Need-supportive teaching and engagement in the classroom: Comparing the additive, synergistic, and global contributions

Elizabeth Olivier[1*], Benoit Galand[2], Alexandre J.S. Morin[1], & Virginie Hospel[2]

[1]Substantive-Methodological Synergy Research Laboratory, Department of Psychology, Concordia University, Canada
[2]Psychological Sciences Research Institut, Faculté de psychologie et des sciences de l'éducation, Université catholique de Louvain, Belgium

*Corresponding author
Elizabeth Olivier
Department of Psychology, Concordia University, Canada
7141 Sherbrooke W., Montreal, QC, Canada, H4B 1R6
(+1)514-848-2424 ext. 3633

Funding : This study was funded by a grant from the Social Sciences and Humanities Research Council (SSHRC) (#756-2017-0223), awarded to Elizabeth Olivier.

This is the prepublication version of the following manuscript:
Olivier, E., Galand, B., Morin, A.J.S., & Hospel, V. (2020). Need-supportive teaching and engagement in the classroom: Comparing the additive, synergistic, and global contributions. *Learning and Instruction*. Early view: https://doi.org/10.1016/j.learninstruc.2020.101389

Abstract

This study contrasts three hypotheses to determine the best configuration of teacher need-supporting practices (autonomy support, structure, and involvement) in terms of classroom-levels of behavioral, emotional, and cognitive engagement. Multilevel analyses were conducted among a sample of 1,193 8th grade students nested in 57 math classrooms. Results failed to support the additive hypothesis (H1), which anticipated that all three practices would be associated with classroom-levels of engagement when jointly considered. Results also failed to support the synergistic hypothesis (H2), which predicted that the greatest benefits would emerge in classrooms characterized by a high level of two or three practices. Finally, results supported the global hypothesis (H3), which anticipated that the global level taken across the three practices—captured by a global factor—would provide optimal support to classroom-levels of engagement. Specific factors representing the imbalance in autonomy support, structure, and involvement also contributed to some aspects of classroom-levels of engagement.

Keywords: student engagement; need-supportive teaching practices; bifactor-confirmatory factor analyses; multilevel analyses

1.Introduction

The increasing demand for individuals with expertise in the disciplines of Science, Technology, Engineering, and Mathematics (STEM) places a lot of pressure on education systems to maximize the number of young people who develop an interest for, and abilities in, math (Xue & Larson, 2015). In addition to helping to increase the availability of competent STEM professionals on the labor market, nurturing students' engagement in math lessons is also likely to have broader repercussions on their school success, career orientation, and ability to transition into the labor market successfully (Martin, Anderson, Bobois, Way, & Vellar, 2012; Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008). Given that math is a school subject for which many students do not have a predilection (Tytler et al., 2008), research on ways to better support math engagement appears particularly important.

Students' math engagement starts in the classroom. According to Self-Determination Theory (SDT), a critical determinant of student engagement involves teachers' adoption of need-supporting teaching practices focused on autonomy support, structure, and involvement (Deci & Ryan, 2000). Although a variety of studies have supported this assertion, in math as well as other school subjects (e.g., Lietaert, Roorda, Laevers, Verschueren, & De Fraine, 2015; Mouratidis, Vansteenkiste, Michou, & Lens, 2013; Stroet, Opdenakker, & Minnaert, 2013), very little attention has been devoted to the combined effects of all three types of practices (Stroet et al., 2013). Studies simultaneously considering teaching practices related to autonomy support, structure, and involvement are so scarce that SDT researchers have not yet reached an agreement regarding the optimal configuration of these practices to support student engagement maximally.

A first possible configuration anticipates that autonomy support, structure, and involvement are all necessary to promote student engagement, and should yield *additive* effects when considered together (e.g., Stroet et al., 2013). This *additive* configuration implies that teachers should use any or all of these practices at the highest possible level, although using only one would still benefit student engagement. A second configuration assumes that the benefits of need-supportive practices are *synergistic* and conditioned on the combined use of the three types of practices (e.g., Reeve, Jang, Carrell, Jeon, & Barch, 2004; Sierens, Vansteenkiste, Goossens, Soenens, & Dochy, 2009). More precisely, this *synergistic* configuration sees each of these practices as necessary but not sufficient to support engagement, suggesting that teachers should incorporate at least a minimal level of each practice in their classroom, although higher levels remain more desirable. A third configuration expects the benefits of need-supportive teaching are maximized when teachers use a globally high level of autonomy support, structure, and involvement across all three practices to provide students with a harmonious learning environment (e.g., Sheldon & Niemiec, 2006). This *global* configuration suggests that autonomy support, structure, and involvement can each contribute to need-supportive teaching, but that teachers should also take care to avoid imbalance across practices.

The lack of knowledge on the best configuration of need-supportive teaching to support student engagement has two consequences (Hospel & Galand, 2016). On the one hand, it makes it difficult to suggest clear recommendations for school practitioners (teachers, psychologists, principals) and stakeholders on what should be a primary target of improvement in the classroom. On the other hand, this lack of knowledge also challenges SDT itself to arrive at a more empirically verified understanding of the role of need-supportive teaching practices for nurturing student engagement. The present study was designed to contrast these three possible configurations of classroom-aggregated student perceptions of the need-supportive teaching practices used by their math teacher in the prediction of student levels of behavioral, emotional, and cognitive engagement in 8th grade.

1.1.Need-Supportive Teaching Practices and Student Engagement

Engagement refers to students' involvement in their learning activities and typically encompasses the behavioral, emotional, and cognitive dimensions (Archambault & Dupéré, 2016; Fredricks, Blumenfeld, & Paris, 2004; Wang & Eccles, 2012). The behavioral dimension refers to the conduct and actions of students. Students can actively participate in class by answering questions asked by the teacher and do the expected assignments. They can also demonstrate a more passive engagement by complying with rules and following instructions. Conversely, other students daydream or pretend to work, which indicates withdrawal or a lack of behavioral engagement (Finn, 1993; Fredricks et al., 2004). Emotional engagement includes all of the affective reactions of students to the learning process and classroom environment. It shows how much they value and identify with their school activities (Finn, 1993; Fredricks et al., 2004). Emotionally engaged students will, for example, report feeling happy, proud, curious, and interested in learning and assignments. Cognitive engagement is the non-visible thought process of students that promotes dedication of effort to learn and master skills. It includes the use of self-regulated and deep-processing strategies, such as making sure to stay focused and concentrated, not letting oneself get distracted, as well as trying to find solutions to solve problems and understand the course material (Fredricks et al., 2004).

SDT positions the need-supportive teaching practices of autonomy support, structure, and involvement as fundamental ingredients of a classroom where students have a desire to invest energy and learn (Connell & Wellborn, 1991; Deci & Ryan, 2000). Autonomy-supportive teachers provide choice, allow students to work at their own pace, acknowledge their perspective, and use informational instead of controlling language (Connell & Wellborn, 1991). They encourage independent thinking, questioning, and constructive criticism from students. Structure is related to the amount and clarity of information given to students about meeting expectations and achieving desired goals, as well as the help and support provided to them to meet these expectations (Deci & Ryan, 2000). Teachers implement structure by stating and explaining explicit rules and instructions and by giving feedback on strengths, weaknesses, and improvements (Connell & Wellborn, 1991). Involvement refers to the extent to which teachers show positive attention to students. Involved teachers dedicate time to know their students, demonstrate care and empathy, show appreciation, and treat students respectfully (Connell & Wellborn, 1991). While teachers can implement these practices in an individualized manner when interacting with individual students, they also implement them at the classroom level as part of their teaching. The present study focuses on this second level of analysis: Teachers' use of autonomy support, structure, and involvement practices involving the whole classroom.

SDT originally anticipated that need-supportive practices would foster student engagement through the satisfaction of their underlying psychological needs for competence, autonomy, and relatedness (Connell & Wellborn, 1991; Deci & Ryan, 2000). More precisely, Jang et al. (2010) have argued that each of the three teaching practices considered here supports student engagement through distinct mechanisms. According to these authors, the benefits of teacher autonomy support are expected to operate through the satisfaction of students' psychological need for volition and autonomy. In contrast, structure is expected to operate through students' perception of being competent at what they do. Finally, involvement is assumed to operate thought students' feelings of relatedness with their teacher. However, recent studies (Olivier, Galand, Hospel, & Dellisse, 2020; Ruzek, Hafner, Allen, Gregory, Mikami, & Pianta, 2016) have shown that the contribution of each teaching practice may not be as specific to each of these three basic psychological need as expected by Jang et al. (2010). For instance, Olivier et al. (2020) have shown that autonomy support and structure may both yield benefits for the satisfaction of the need for autonomy in addition to the need for competence, and Ruzek et al. (2016) has shown that teacher involvement may also positively impact the satisfaction of the needs for autonomy and competence. Moreover, empirical research has demonstrated that attending a classroom where the teacher uses all three practices tends to directly benefit all three facets of student engagement, even without considering the possible intermediate mediator role of need satisfaction (Jang, Reeve, & Deci, 2010; Liu & Chiang, 2019; Mouratidis et al., 2013; Reeve et al., 2004; Skinner & Belmont, 1993; Wang & Holcombe, 2010; Weyns, Colpin, De Laet, Engels, & Verschueren, 2018; Zhao, Song, Zhao, & Zhang, 2018). As such, SDT also incorporates a postulate for the direct association between need-supportive practices and student engagement (e.g., Skinner, Furrer, Marchand, & Kindermann, 2008), which corresponds to the approach taken in this study to assess the role of teacher need-supportive practices. Finally, some studies focusing on student need satisfaction refer to teachers' practices as being supportive of the needs for autonomy, competence, and relatedness (Bean, Rocchi, & Forneris, 2019; Sheldon & Filak, 2008; Zhang, Solomon, & Gu, 2012). Yet, as this study focuses on teachers' practices and student engagement without considering the intermediate role of psychological needs, we rely on the original conceptualization of teachers' practices proposed by Connell and Wellborn (1991) and Deci and Ryan (1985), namely focusing on autonomy support, structure, and involvement.

As part of an extensive review of the literature on how need-supportive teaching relates to student engagement, Stroet et al. (2013) state that there was enough evidence to conclude that the three practices assessed separately all support student engagement. However, these researchers also noted that the combined role of all three practices had not yet been adequately documented due to a dearth of research considering more than one practice at a time. Studying various configurations of need-supportive teaching necessitates accounting for methodological and conceptual considerations to obtain a rigorous assessment of the optimal learning environment for students.

1.2.Methodological Considerations

A careful investigation of the benefits of exposing students to a need-supportive learning environment requires researchers to account for (a) the source of evaluation of need-supportive teaching, (b) the level of analysis, and (c) the past experiences of students that may impact their engagement. First, when studying teaching practices as part of the learning environment shared by students in the same classroom, focusing solely on individual student perceptions of these practices is not appropriate (Marsh et al., 2012). More specifically, when students are asked to rate the practices used by their teacher in relation to all students in the classroom, individual student reports come to reflect individual differences, personal experiences, or idiosyncratic biases, in addition to providing a partial depiction of what truly happens in the classroom (Lüdtke, Robitzsch, Trautwein, & Kunter, 2009). Teachers' reports of their own practices can also be biased by social-desirability and self-consistency tendencies (Feldon, 2007). To overcome these limitations, some suggest aggregating the perceptions of students at the classroom level as a way to focus on the shared components of students' perceptions, thereby eliminating inter-individual differences in perceptions (Kunter & Baumert, 2006; Lüdtke et al., 2009; Marsh et al., 2012). In this approach, all students from a classroom are considered interchangeable informants on the practices of their teacher (Marsh et al., 2012), which reduces idiosyncratic biases and ultimately allows for the generation of recommendations for classroom functioning (Lüdtke et al., 2009). This study relies on such an aggregated measure.

Second, several students are exposed to the practices of a single teacher. As students are nested within nonequivalent classrooms, those attending different classrooms may have slightly different academic functioning. The peer composition of the classroom can vary (e.g., gender composition, number of students having had to repeat a grade, average levels of achievement and engagement, and average SES; Fauth et al., 2019; Wang & Eccles, 2012), in a way that may impact students' functioning. For instance, students enrolled in classrooms with a higher average SES, higher average achievement, and proportionally more girls, have been found to have a higher average level of achievement and engagement (De Fraine, Van Damme, Van Landeghem, Opdenakker, & Onghena, 2003; Hospel & Galand, 2016). Moreover, distinct teachers also use different teaching practices. Teaching practices are an inherent characteristic of a classroom and should be studied as such, through multilevel analyses able to specifically focus on the shared component of classroom perceptions (Marsh et al., 2012). These analyses make it possible to assess the unique contribution of a shared classroom environment (i.e., need-supportive teaching) to the prediction of the collective engagement of students sharing the same classroom, rather than having to focus on the confusing mixture of information that is encapsulated into students' individual perceptions of their classroom (i.e., teaching practices, perceptual differences, differential treatment, personal biases, and idiosyncratic considerations: Marsh et al., 2012). Again, studying teaching practices and their contribution to collective classroom engagement contributes to understanding how to improve whole classroom functioning. Thus, this study considers this relation via the implementation of multilevel analyses, while controlling for the peer composition of the classroom.

Finally, students' current levels of engagement are, in part, the result of their past experiences, probably at least as much as of their current classroom environment. These past experiences can be captured, to a substantial extent, by students' previous levels of engagement as engagement levels tend to remain relatively stable over time (Archambault & Dupéré, 2016; Wang & Eccles, 2012). This means that achieving a clear understanding of the contribution of need-supportive teaching practices should strive to document the role of these practices over and above the influence of past levels of engagement (reflecting their past classroom experiences). Studies carried at a single time-point are unable to account for these past experiences. Existing research shows that the benefits of autonomy support, structure, and involvement remain after accounting for previous levels of engagement and achievement (Reeve, Jang, et al., 2004; Skinner & Belmont, 1993; Wang & Eccles, 2013). Our study similarly accounts for prior levels of engagement at the individual and classroom levels, as well as for classroom composition characteristics. Along with accounting for these variables, the study also controls for known individual confounders of student engagement. Students from more advantageous backgrounds (i.e., higher SES) are generally more engaged in their schoolwork (Wang & Degol, 2014; Wang & Eccles, 2012). Similarly, students with a history of high achievement or, in contrast, grade retention, may be subject to engagement variations (Archambault & Dupéré, 2016; Hospel & Galand, 2016; Wang & Eccles, 2012). Finally, boys are sometimes found to be more engaged in math and STEM-related subjects

(Wang & Degol, 2014).

1.3.Conceptual Considerations

Existing studies, summarized in Table 1, have assessed the contribution of need-supportive teaching to student engagement as a function of three possible configurations (*additive*, *synergistic*, and *global*), each relying on distinct assumptions regarding the combined influence of autonomy support, structure, and involvement on student engagement.

1.3.1.Additive Contribution

The *additive* hypothesis states that autonomy support, structure, and involvement each have a unique (each practice affects student engagement), and additive (all three practices have independent effects on engagement when simultaneously considered) contribution to the prediction of student engagement. Only five studies have included autonomy support, structure, and involvement in a single analysis (see Table 1). Among these, three studies conducted at the student level did not find an additive contribution of the three need-supportive practices (Leflot, Onghena, & Colpin, 2010; Lietaert et al., 2015; Skinner & Belmont, 1993). The remaining studies were conducted at the school level and found support for an additive contribution of the three practices to student engagement (De Naeghel et al., 2014; Wang & Eccles, 2013). However, the results from these two studies remain complicated by the school level of analyses, making it impossible to more directly assess the impact of practices used by individual teachers when teaching their own classroom. Thus, evidence for the additive contribution of need-supportive practices at the classroom levels is currently lacking.

1.3.2.Synergistic Contribution

The *synergistic* hypothesis is that each of the three need-supportive practices is necessary, but that neither of them is sufficient, to support engagement. Support for this hypothesis would come from studies showing that classrooms in which two, or ideally three, need-supportive practices are routinely used tend to produce higher levels of student engagement than classrooms in which a single one of these practices is used (Reeve, Deci, & Ryan, 2004). Researchers have used three alternative methods to assess this hypothesis (see Table 1): cluster analyses (Leenknecht, Wijnia, Loyens, & Rikers, 2017; Vansteenkiste et al., 2012), latent profile analyses (Holzberger, Praetorius, Seidel, & Kunter, 2019), or tests of interaction (moderation) effects (Hospel & Galand, 2016; Mouratidis, Michou, Aelterman, Haerens, & Vansteenkiste, 2018; Nie & Lau, 2009; Sierens et al., 2009). Overall, regardless of the method used (clusters, profiles, or interactions, multilevel or not, accounting for past engagement or not), no consistent pattern of results emerge from these studies, leaving a still open question to the possibility that need-supportive practices could have a synergistic effect on engagement. Theoretically, this may indicate that need-supportive teaching practices are not dependent on each other’s presence to optimally support student engagement (Reeve et al., 2004), thus calling into question the appropriateness of the synergetic hypothesis when need-supportive teaching practices are considered. Importantly, among the studies reporting tests of interactions effects, no research has assessed a three-way interaction between the three practices and student engagement, which is an objective of the present study.

1.3.3.Global Contribution

Deci and Ryan (2000) theoretically argue that an optimal learning environment is one in which the teacher relies on autonomy support, structure, and involvement interconnectedly. In fact, according to SDT, a social context, such as a classroom, that supports the satisfaction of one need generally also support the satisfaction of the other two needs, through the use of all three practices (Ryan & Deci, 2017). In contrast, teachers relying on a single one of these practices would induce an imbalance in the classroom that could negatively impact students. Thus, SDT postulates that “people cannot meaningfully thrive through the satisfaction of one need alone” (p. 250, Ryan & Deci, 2017). Inspired by studies assessing global need satisfaction (i.e., the benefits of a global level of satisfaction of one’s need for autonomy, competence, and relatedness: Dysvik, Kuvaas, & Gagné, 2013; Garn, Morin, & Lonsdale, 2019; Gillet, Morin, Huart, Colombat, & Fouquereau, 2019; Sheldon & Niemiec, 2006), this study also investigates the possibility that autonomy support, structure, and involvement best support student engagement when teachers use all of them at a globally high level without using any of them in an imbalanced manner relative to the other ones. A global configuration reflects the interconnected nature of need-supportive teaching such that the best learning environment should be one in which students are exposed to all practices at a globally high level. In addition, the global hypothesis suggests that despite the inherently desirable nature of all three practices, exposure to them in an imbalanced manner would not benefit students and may even carry a risk for their engagement. For instance, autonomy support without the balancing benefits of some structure could lead to disengagement. Conversely, too much structure without involvement might also stifle engagement.

The *global* hypothesis addresses one key issue overlooked by studies of additive or synergistic configurations. Indeed, the correlation typically reported among all three practices (r=.50 to .87) suggests a high degree of correspondence between them and making prediction models unstable because of potential multicollinearity (e.g., Aelterman, Vansteenkiste, Haerens, Soenens, Fontaine, & Reeve, 2019; Holzberger et al., 2019; Leflot et al., 2010; Lietaert et al., 2015; Mouratidis et al., 2018; Tóth-Király, Morin, Gillet, Bothe, Nadon, Rigó, & Orosz, In press). However, these correlations do not simply reflect the presence of an empirical overlap between autonomy support, structure, and involvement. Rather, they suggest that, in accordance with the global hypothesis, these three practices also share common features. For example, teachers who take into consideration their students' opinions are thought to be autonomy-supportive, and teachers who demonstrate care and empathy are thought to show involvement. Yet, students are likely to perceive that teachers who use such practices are generally need-supportive, without differentiating that the behaviors specifically tap into autonomy support and involvement. Therefore, as these teacher behaviors are closely related, students who perceive that their teacher uses one of the three practices are likely to report that their teacher uses the other two practices in tandem. This generalized tendency to jointly use these practices suggests that attempts to disentangle their additive or synergistic contribution may not reflect what really happens in the classroom.

Although the possibility of a global configuration of need-supportive teaching has never yet been directly investigated, a few SDT-based studies discuss this possible hypothesis about the satisfaction of the basic psychological needs for autonomy, competence, and relatedness. This hypothesis was first proposed by Sheldon and Niemiec (2006), who showed that employees' well-being was maximized when their three needs were (even moderately) globally satisfied, above the imbalanced high satisfaction of a single need. Dysvik et al. (2013) further investigated this idea by comparing the additive, synergistic, and global configuration of need satisfaction and concluded that global satisfaction benefited the most employee motivation, although the procedure used by these authors to contrast synergistic and global effects introduced statistical redundancy in the model (Gillet et al., 2019). In this study, we postulate that similar principles apply to autonomy support, structure, and involvement (Deci & Ryan, 2000; Reeve, Deci, et al., 2004).

These earlier SDT studies (Dysvik et al., 2013; Sheldon & Niemiec, 2006) referred to this hypothesis as focusing on the "balanced" contribution of psychological need satisfaction. However, these authors relied on an indirect operationalization of balance involving the calculation of difference scores rather reflecting the extent to which the satisfaction of each need was in a state of imbalance relative to the other needs. Thus, they assume that the main driver of positive effects was the global level to which all needs were satisfied, and the lack of imbalance among them, leading us to refer to this hypothesis as one focusing on global effects. The reliance on difference scores represented another key limitation of these earlier studies. As noted by Gillet et al. (2019), difference scores are notably sensitive to measurement errors, and those used by these earlier studies were also statistically redundant with the interaction effects used to test the synergistic hypothesis, as both are a transformation involving the same combination of two variables.

This study relies on the bifactor method proposed by Gillet et al. (2019) to assess the global contribution of need-supportive teaching. A bifactor model identifies a global factor (G-factor) reflecting the commonality present in ratings of all items used to assess autonomy support, structure, and involvement. This need-supportive G-factor reflects teachers' global provision of autonomy support, structure, and involvement to their students. The bifactor model also identifies subscale-specific (autonomy support, structure, and involvement) orthogonal (i.e., uncorrelated) factors (S-factors) reflecting the commonality shared across all items forming a subscale but left unexplained by the G-factor. These autonomy support, structure, and involvement S-factors directly capture the extent to which each practice is used in an imbalanced manner by the teacher (e.g., the score on the structure S-factor would be high when teachers tend to rely on this practice over and above their global level of reliance on all three practices). When used in prediction, this approach thus makes it possible to assess the effects of global levels of need-supportive teaching practices while also considering whether there could be further benefits, or harm, associated with imbalanced use of each specific practice.

Research conducted in the SDT framework has supported a bifactor representation of student motivation (e.g., Gillet et al., 2018; Litalien et al., 2017) or need satisfaction (e.g., Garn et al., 2019; Gillet et al., 2019; Sánchez-Oliva et al., 2017; Tóth-Király, Morin, Bőthe, Orosz, & Rigó, 2018). However, no research has yet relied on this approach to assess need-supportive teaching. A few studies have investigated the contribution of a global measure of need-supportive teaching, but without the joint consideration of specific levels of need support (see Table 1: Klem & Connell, 2004; Skinner et al., 2008; Tucker et al., 2002; Zimmer-Gembeck, Chipuer, Hanisch, Creed, & McGregor, 2006). These studies clearly show that this global measure of need-supportive practices is always associated with higher student engagement, whether or not the model controlled for previous levels of engagement. However, none of these studies have taken into account the nested organization of students within classrooms.

1.4.Aims and Hypotheses

The contribution of this study lies in the investigation of the additive, synergistic, and global hypotheses concerning the joint effects of need-supportive teaching practices (i.e., autonomy support, structure, and involvement) on students' levels of behavioral, emotional, and cognitive engagement in math at the classroom level.

A preliminary objective of the study is to validate the results from prior studies by confirming the associations between each practice—autonomy support, structure, and involvement—and classroom-levels of engagement in the context of separate models. We anticipate that all three practices will significantly contribute to classroom-levels of engagement when the other two practices are not considered. Following this preliminary verification, tests of the three alternative hypotheses, illustrated in Figure 1, will be conducted in the following sequence:

(1) First, we investigate the additive contribution hypothesis (H1). If this hypothesis is confirmed, the three practices, when assessed in a single model, will be all significantly associated with classroom-levels of engagement. Although supported by theory (Connell & Wellborn, 1991; Ryan & Deci, 2000), there is currently no empirical evidence to support this hypothesis.

(2) Second, we assess the synergistic contribution hypothesis (H2). If this hypothesis is confirmed, classroom-levels of engagement will be maximized when teachers use a high level of two or all three practices simultaneously. Current evidence is mitigated for this hypothesis.

(3) Third, we assess the global contribution hypothesis (H3). If this hypothesis is confirmed, the global factor will be positively related to classroom-levels of engagement with no additional effect of the specific factors. Although direct research evidence is lacking for this hypothesis, indirect evidence from research on need satisfaction leads us to expect support for H3.

All three hypotheses will be tested among a sample of 8th grade students using multilevel analyses accounting for prior student engagement in math (7th grade). The models also include controls for known confounders of engagement at the student and classroom levels: student gender, family SES, knowledge in math, and grade retention (as all students are in 8th grade, the grade retention variable captures any significant age variation).

2.Methods

2.1.Sample

This research relies on a sample of 1,193 8th grade students recruited within 11 secondary public schools located in the French-speaking part of Belgium[1]. Students came from diverse socio-cultural backgrounds. The study was conducted over two school years, with measures of prior levels of engagement and background controls taken when students where in 7th grade, which is the first year of secondary school following the transition from primary school in the Belgian school system. In 8th grade, these students were nested in 57 classrooms, aged between 12 and 16 years old (M=13.61, SD=0.83), 50% of them are girls, and 38% have repeated at least one school year. This proportion of grade repeaters corresponds to the norm in French-Speaking Belgium (Fédération Wallonie-Bruxelles, 2018).

2.2.Procedure

The ethics committee of the [name of the university] approved of the research project. The research team obtained active consent from school authorities and students. No incentives were given for participation. Students were informed that their participation was voluntary and that responses would be kept confidential. With the approval of local school authorities and the ethics committee of the [name

[1] In the Belgian school system, there is no tacking before 9th grade.

of the university], a procedure of passive consent was used with parents to ensure representativeness (Pokormy, Jason, Schoeny, Townsend, & Curie, 2001). Thus, parents received a letter informing them of the research project and had to return it if they did not agree with their child participating. Students were invited to fill in a paper-and-pencil questionnaire and a math knowledge test twice. The first data collection took place in the Spring of their 7th grade (2013-2014) and the Winter of their 8th grade (2014-2015). Teachers were asked to leave the classrooms while a trained research assistant supervised all data collection, including the math test and the questionnaire.

2.3.Measures

2.3.1.Individual Sociodemographic Controls. Students reported their gender (0=male; 1=female) and if they had ever repeated a school year (0=never retained; 1=retained once or more). The study also included two indicators of SES based on measures previously used by the Organization for Economic Co-Operation and Development (OECD, 2017) in the Programme for International Student Assessment (PISA). A first measure consisted of educative possessions (e.g., "Do you have access to literature books at home.") and a second measure consisted of educative resources (e.g., "Do you have a quiet room to study?") available at home (Rutkowski & Rutkowski, 2013). Students rated these items on a two-point scale (0=no; 1=yes).

Students' math knowledge was assessed in 7th grade using a 28 short-answer test, which is the test used by the Belgian Ministry of Education in official certification assessments that all students undertake at the end of their 8th grade (Fédération Wallonie-Bruxelles, 2019). This test included questions about all domains studied in the 7th- and 8th-grade math curricula: numbers (16 questions), sizes and measures (4 questions), figures and solids (4 questions), and data treatment (4 questions). Each question was coded 0=Fail or 1=Success. The global score consisted of a sum of all 28 items (ranging from 0 to 28), which was then converted to a 0 to 10 scale. This measure of student knowledge in math had a satisfactory scale score reliability (α=.80).

2.3.2.Classroom Composition (Controls). Measures of classroom composition were calculated as the ratio of male-to-female students, and grade repeaters to on-time students per classroom (e.g., Marsh et al., 2012). We also calculated average classroom levels on the educative possession items, educative resources items, and math knowledge test. Finally, average classroom levels of student behavioral, emotional, and cognitive engagement in 7th grade were also considered as classroom-level controls.

2.3.3.Need-Supportive Teaching. Students rated the autonomy support, structure, and involvement practices used by their 8th grade math teacher. Items were drawn from existing scales (Belmont, Skinner, Wellborn, & Connell, 1988; Reeve & Halusic, 2009), translated into French (using a standardized translation back-translation procedure with independent bilingual translators), and adapted to math lessons. Students rated the items on a five-point scale from 0 (totally false) to 4 (totally true). Previous studies supported the validity and reliability of the French version of those scales (Hospel & Galand, 2016; Olivier et al., 2020). Autonomy Support included seven items tapping into choice, relevance, and respect of students' opinions and rhythm (e.g., "My teacher offers to choose between different activities"; α=.79). Structure included seven items tapping into expectancies, contingency, instrumental help, and adjustment of teaching strategies (e.g., "My teacher gives clear and comprehensive rules"; α=.84). Involvement included seven items tapping into attunement and dedication of resources and dependability (e.g., "My teacher shows sincere interest in students"; α=.82).

We created two distinct sets of need-supportive teaching scores, based on different methods, to address each of our research questions. First, to assess the first (additive contribution) and second hypothesis (synergistic contribution), we used Confirmatory Factor Analyses (CFA) to create factor scores of autonomy support, structure, and involvement. This factor structure is reported in Figure 2. Second, to assess the third hypothesis (global contribution), we relied on a Bifactor CFA. In a bifactor CFA, all items load on a global factor as well as on their a priori subscale-specific factor. All factors are orthogonal. This factor structure is displayed in Figure 3. The global factor also had good reliability (α=.91). Factor scores aggregated at the classroom level were used in subsequent analyses, allowing us to exert some degree of control for unreliability (DiStefano, Zhu, & Mindrila, 2009). Both the CFA and bifactor-CFA were found to be invariant across genders (see Appendix B).

2.3.4. Engagement. Students rated their behavioral, emotional, and cognitive engagement in math lessons on a scale ranging from 0 (never) to 4 (very often). Behavioral engagement was measured using a 10-item scale (7th grade α=.85; 8th grade α=.86; Hospel, Galand, & Janosz, 2016). The measure included items tapping into student compliance, participation, and withdrawal (e.g., "When the teacher asks a question during a lesson, I try answering."). Emotional engagement consisted of a 7-item measure (7th-grade α=.77; 8th-grade α=.80) of positive emotions in math lessons (e.g., I feel happy and fulfilled."; Galand & Philippot, 2005). Cognitive engagement is an 11-item measure (7th-grade α=.79; 8th-grade α=.80), including student self-regulation and use of learning strategies (e.g., "I check for mistakes before handing in assignments."; Galand, Raucent, & Frenay, 2010). The a priori factor structure was verified using CFA and found to be invariant over time and between genders (see Appendix A and B). All of the main analyses were conducted using factor scores saved from this CFA.

2.4.Analytic Strategy

We tested multilevel path analysis models using Mplus 8.2 (Muthén & Muthén, 2019). In these models, predictors modeled at the classroom level (i.e., need-supportive practices) were allowed to predict the classroom level variance in outcomes modeled at the student level (i.e., student engagement). These models were estimated using the factor scores obtained from the preliminary measurement models described previously in relation to each measure. For the need-supportive practices, these factor scores were then aggregated at the classroom level using a manifest aggregation method (Marsh et al., 2009). In contrast, factor scores reflecting engagement were aggregated at the classroom level using a latent aggregation approach to correct for inter-rater differences (Marsh et al., 2009, 2012). Unfortunately, it was not possible to rely on doubly-latent multilevel models (providing a complete correction for inter-item and inter-rater reliability across levels) in the present study. Indeed, attempts to do so systematically resulted in non-converging or improper solutions, suggesting overparameterization and the need to rely on simpler models (Lüdtke et al., 2011; Marsh et al., 2009). For this reason, we opted for an alternative approach recommended by Lüdtke et al. (2008), which is to rely on manifest aggregation of the predictors and latent aggregation of the outcomes. Moreover, factor scores allowed to us to maintain at least some level of control for inter-item measurement error in relation to need-supportive practices and engagement, whereas the latent aggregation approach allowed us to obtain classroom level estimates of engagement corrected for inter-rater reliability (Lüdtke et al., 2009; Marsh et al., 2012).

These analyses relied on the Maximum Likelihood Robust (MLR) estimator and Full Information Maximum Likelihood estimation to account for missing data. Students with missing data (N=488) were kept in the sample. Rates of missing data ranged between 1.03% (grade retention variable) to 31.01% (math knowledge test in 7th grade). Comparing students without and with missing data revealed no difference in emotional engagement (t=.67, p=.506), whereas the behavioral (t=3.63, p<.001) and cognitive (t=3.46, p<.001) engagement of students without missing data was slightly higher (0.12 on a scale ranging from 0 to 4).

Using a sequential procedure (Raudenbush & Bryk, 2002), we first assessed a null model, without predictors, to estimate the part of the variance of student behavioral, emotional, and cognitive engagement occurring at the student and classroom levels. We then introduced the covariates at the student level (7th grade engagement, gender, educative possessions, educative resources, grade retention, and 7th grade math knowledge) and at the classroom level (gender ratio, average educative possessions, average educative resources, ratio of grade repeaters, and average 7th grade math knowledge, average level of student engagement in 7th grade) in a second model. All variables were grand-mean centered, except for dichotomous variables for which zero is meaningful (gender and grade retention) (Opdenakker & Van Damme, 2001). To maximize parsimony, only covariates with a significant contribution to student engagement were retained (Véronneau, Vitaro, Brendgen, Dishion, & Tremblay, 2010). We then estimated three preliminary models to assess the unique contribution of autonomy support (Model 0.1), structure (Model 0.2), and involvement (Model 0.3) (see Figure 1).

Following the preliminary analyses, H1 (additive; see Model 1 in Figure 1) was assessed in a first multilevel model in which all three dimensions of engagement were regressed on the three need-supportive teaching practices (CFA) at the classroom level. H2 (synergistic; see Model 2 in Figure 1) was assessed by adding the two- and three-way interactions between the practices (CFA) at the classroom level to the previous model. H3 (global; see Model 3 in Figure 1) was assessed by regressing the three dimensions of engagement on teaching practices G- and S- factors (bifactor CFA) at the classroom level.

We assessed model fit using a variety of goodness-of-fit indicators (Hu & Bentler, 1999; Marsh, Hau, & Grayson, 2005). Although we report the chi-square test of exact fit, we do not use it to assess model fit given its known oversensitivity to sample size and minor misspecifications (Marsh et al., 2005). The Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) indicate an excellent fit when above .95, and an acceptable fit when above .90. The Root Mean Square Error Approximation (RMSEA) and the Standardized Root Mean Square Residual at the within level ($SRMR_w$) and at the between level ($SRMR_b$) indicates an excellent fit when lower than .06 and an acceptable fit when lower than .08.

3.Results

3.1.Preliminary Analyses

3.1.1.Descriptive statistics. All correlations at the student and classroom levels were in the expected direction (see Table 2). The three teaching practices were positively related to the three dimensions of student engagement. The correlations between the CFA factor scores for autonomy support, structure, and involvement were above 0.84 at the student level and above 0.90 at the classroom level, suggesting potential conceptual overlap and risk of multicollinearity, but also supporting the value of adopting a bifactor approach allowing one to disaggregate the common core underlying each practice from their unique specificity.

For the CFA and bifactor-CFA configurations of need-supportive practices, we also assessed the ICC(1) (i.e., proportion of variance occurring at the classroom level) and the ICC(2) (i.e., the level of inter-rater agreement between students' rating within classrooms) (Lüdtke et al., 2009). Whereas ICC(1) values greater than .10 (10% of variance occurring at the classroom level) suggest the presence of enough classroom-level variability to support multilevel analyses, ICC(2) values can be interpreted as any other estimate of reliability (Marsh et al., 2012; Morin et al, 2014). In the CFA configuration, the results revealed sufficient variability at the classroom level, and adequate levels of inter-rater reliability (autonomy support: ICC(1) = .304; ICC(2) = .899; structure: ICC(1) = .327; ICC(2) = .908; involvement: ICC(1) = .351; ICC(2) = .917). In the bifactor-CFA configuration, the G-factor (ICC(1) = .328; ICC(2) = .909) and the involvement S-factor (ICC(1) = .201; ICC(2) = .837) also presented sufficient classroom-level variability and inter-rater reliability. In contrast, the autonomy support (ICC(1) = .054; ICC(2) = .537) and structure (ICC(1) = .062; ICC(2) = .573) S-factors appeared to be more weakly defined at the classroom level. Interestingly, these results are generally aligned with those from previous studies in which greater (Aelterman et al., 2019), but also lower (Wagner et al., 2016), ICC(1) values have previously been reported.

***3.1.2.Null model: Between-classroom variance*.** The null model (without predictors) revealed that respectively, 5.30%, 2.52%, and 4.88% of the variance of behavioral, emotional, and cognitive engagement occurred at the classroom level.

***3.1.3.Covariates model: Controlling for individual characteristics and classroom composition*.** Preliminary analyses of covariates effects were used to select the statistically significant covariates to retain for further analyses (Véronneau et al., 2010). At the student level, significant covariates associated with behavioral engagement in 8th grade were behavioral and cognitive engagement in 7th grade, educative possessions, and educative resources. Significant covariates associated with emotional engagement in 8th grade were emotional and cognitive engagement in 7th grade, student gender, educative resources, and math knowledge. Significant covariates associated with cognitive engagement in 8th grade were cognitive engagement in 7th grade, educative possessions, and educative resources. None of the covariates had a significant contribution at the classroom level, and thus, none were included in the following models.

***3.1.4.Model 0: Preliminary tests of isolated dimensions of need-supportive practices*.** We assessed if the three need-supportive practices (CFA) entered in separate regression models were associated with behavioral, emotional, and cognitive engagement at the classroom level in 8th grade. The three models had an acceptable fit to the data (Autonomy support: χ^2=41.84, df=9; CFI=.99; TLI=.98; RMSEA=.06; $SRMR_w$ = .02; $SRMR_b$ = .03; Structure: χ^2=41.21, df=9; CFI=.99; TLI=.98; RMSEA=.05; $SRMR_w$ = .02; $SRMR_b$ = .03; Involvement: χ^2=39.92, df=9; CFI=.99; TLI=.98; RMSEA=.05; $SRMR_w$ = .02; $SRMR_b$ = .03). Results indicate that all three practices were related to classroom-levels of engagement beyond the contribution of covariates (see Table 3).

3.2.Model 1: Additive Contribution (H1)

We assessed whether, when simultaneously considered in a single model, all three need-supportive practices (CFA) significantly contributed to the three dimensions of classroom-levels of engagement. Results from these analyses, which resulted in an acceptable level of fit to the data according to all indicators (χ^2=37.92, df=9; CFI=.99; TLI=.98; RMSEA=.05; $SRMR_w$ = .02; $SRMR_b$ = .02), are displayed in Table 4. These results showed that none of the classroom-level need-supportive practices were significantly related to any dimension of classroom-levels of engagement, consistent with a lack of additive contribution.

3.3.Model 2: Synergistic Contribution (H2)

We then added the two- and three-way interactions between the three need-supportive teaching practices (CFA) to Model 1. We first incorporated the two-way interactions (autonomy support × structure; autonomy support × involvement; structure × involvement). The results are reported in Table 4. The model had an acceptable level of fit to the data (χ^2=51.45, df=9; CFI=.99; TLI=.96; RMSEA=.06; $SRMR_w$ = .02; $SRMR_b$ = .02). The classroom level explained variance in collective levels of engagement was larger in Model 2 than in Model 1. Adding the interactions brought the statistical significance of the association of structure with classroom-levels of behavioral engagement below the threshold of $p < .05$. Only one interaction was significantly associated with classroom-levels of emotional engagement. Simple slope analysis revealed that in classrooms with low levels of structure, autonomy support was associated with lower classroom-levels of emotional engagement (*b*=-1.07 (SE=.58), *p*=.038), whereas in classrooms with high levels of structure, autonomy support was not associated with classroom-levels of emotional engagement (*b*=1.12 (SE=.67), *p*=.096). We then added the three-way interaction (autonomy support × structure × involvement), which did not further contribute to explaining classroom-levels of engagement with *p*-values ranging between .206 and .969 (χ^2=100.54, df=9; CFI=.98; TLI=.91; RMSEA=.08; $SRMR_w$ = .02; $SRMR_b$ = .02). These results are consistent with a lack of synergistic effect.

3.4.Model 3: Global Contribution (H3)

In the third and final model, we assessed the contribution of the global and specific need-supportive teaching practices (bifactor-CFA) to classroom-levels of engagement (χ^2=37.61, df=9; CFI=.99; TLI=.98; RMSEA=.05; $SRMR_w$ = .02; $SRMR_b$ = .02). The results are reported in Table 4. Compared to Model 1, Model 3 explained a larger amount of classroom-level variance in behavioral and cognitive engagement and the same amount of classroom-level variance in emotional engagement. The classroom-level G-factor (global need-supportive practices) was significantly associated with classroom-levels of behavioral, emotional, and cognitive engagement beyond the contribution of covariates. The S-factors (reflecting an imbalanced use of autonomy support, structure, and involvement practices) had an additional contribution to the prediction of classroom-levels of engagement. The autonomy support specific factor positively contributed to classroom-levels of emotional engagement, the structure S-factor positively contributed to all three dimensions of classroom-levels of engagement, and the involvement specific factor positively contributed to classroom-levels of behavioral engagement.

4.Discussion

In their presentation of SDT, Deci and Ryan (2000) state that "psychological health requires satisfaction of all three needs [autonomy, competence, and relatedness]; one or two are not enough" (p.229). This statement seems eloquent at first—the three needs absolutely have to be fulfilled—but bears important grey areas when it comes to knowing *how* to fulfill them. Supporting these needs in the classroom requires a wise combination of autonomy support, structure, and involvement. Should teachers use as much as they can of each of these three practices (H1)? Can teachers still support students' needs and engagement if they only use a high level of one or two of those practices (H2)? Should teachers rather focus on maximizing their global use of the three practices to create a harmonious learning environment, and in this context, is there a risk to relying on imbalanced level across practices (H3)? Unfortunately, research has not yet informed the optimal configuration of these need-supportive teaching practices to maximally support student engagement.

Relying on SDT, this study assessed three competing hypotheses regarding the nexus between these three need-supportive teaching practices and classroom-levels of behavioral, emotional, and cognitive engagement. The study focused on engagement in math classes, as this is a school subject for which there is a need to develop students' interest early on (Tytler et al., 2008). Our results failed to support the additive hypothesis (H1) by showing that none of these practices, when considered together, contributed independently to the prediction of students' classroom-levels of engagement. Results also failed to support the synergistic hypothesis (H2). Although the results revealed a significant interaction effect between practices in the prediction of students' classroom-levels of emotional engagement, the negative effect of autonomy support in the absence of structure was inconsistent with the synergistic hypothesis. Finally, results supported the global hypothesis (H3), revealing that the global use of autonomy support, structure, and involvement seemed to provide a nurturing context for student engagement at the classroom level. Moreover, the results revealed unexpected benefits associated with the specific use of each practice above their joint contribution. This result thus supports that teachers could maximize their use of each practice without having to worry about creating imbalance, as long as all practices are implemented to some extent in the classroom.

4.1.Student Engagement within an Individual and Classroom Context

A proper investigation of the benefits of a learning environment to student engagement requires careful consideration of individual and group background characteristics. Our results confirm that some of the students' individual characteristics were associated with their engagement, particularly their previous levels of math engagement (Archambault & Dupéré, 2016; Wang & Eccles, 2012). The results also showed that the three dimensions of student engagement fluctuated slightly (2.52% to 5.30%) across classrooms, although these fluctuations were not the result of classroom composition characteristics. These between-classroom variations were smaller than the usual recommendations for conducting multilevel analyses (10%), but similar to the student engagement classroom variations usually reported in other studies (e.g., Holzberger et al., 2019; Nie & Lau, 2009) and to classroom variations typically reported in educational research focusing on nonperformance measures (e.g., Hedges & Hedberg, 2007). As expected, need-supportive teaching practices explained a large proportion of this between-classroom variation in student engagement, but some configurations of practices seemed better than others to support young learners' engagement in math. It would be interesting for future studies to combine similar aggregated measures of student perceptions, with additional measures (teacher reports, observational data) taken directly at the classroom level to obtain an even clearer perspective on the classroom reality.

4.2.Absence of Additive and Synergistic Contributions

As expected, our preliminary analyses showed that, when assessed in separate models, classroom perceptions of autonomy support, structure, and involvement all contributed to students' classroom-levels of behavioral, emotional, and cognitive engagement. These results, consistent with prior results (Jang et al., 2010; Liu & Chiang, 2019; Mouratidis et al., 2013; Reeve, Jang, et al., 2004), support the adequacy of the measures used in this study to capture students' perceptions of the autonomy support, structure, and involvement practices used by their teacher. However, when assessed together, these practices did not display the expected additive contribution (H1) to student engagement, as no practice was found to predict any dimension of engagement in this model. Besides, these practices were also not consistently found to interact synergistically in the prediction of classroom-levels of engagement (H2)[2].

When considering this lack of additive and synergistic effects, it is important to note that this study, as well as other studies (e.g., Aelterman et al., 2009; Holzberger et al., 2019; Leflot et al., 2010; Lietaert et al., 2015; Mouratidis et al., 2018), have shown autonomy support, structure, and involvement to be highly correlated, suggesting potential multicollinearity. The strength of these correlations may explain why associations apparent in models involving a single practice fade out when all three practices are considered. As such, observing a lack of additive or synergistic contribution should not be taken as evidence that some of these practices are more or less important than others for student engagement. They simply suggest that teachers using one type of practice also tend to use the other types, making it difficult to isolate unique or interactive effects, which may not reflect classroom reality. However, from a theoretical perspective, these results suggest the additive or the synergistic hypotheses might not provide an optimal representation of the combined role played by need-supportive teaching practices, at least as more specifically applied to math classrooms. More precisely, all three need-supportive teaching practices do not seem to play a similar additive role in the prediction of classroom-levels of

[2] A single interaction effect was found and suggested that combining high levels of autonomy support and structure did not benefit nor alter student engagement. Yet, it showed that providing a lot of autonomy support without a sufficient level of structure led to a decrease in emotional engagement. Although this result could indicate that a certain level of structure is required to avoid potential drawbacks of autonomy support for student emotional engagement, it is not consistent with existing theoretical propositions and some empirical findings (e.g., Deci & Ryan, 2000; Mouratidis et al., 2018). Moreover, this interaction was limited to a single dimension of student engagement. As such, we anticipate that it might simply stem from the failure of this model to fully capture the global contribution of need-supportive practices.

engagement, and the effects of each practice do not seem to depend on the presence of the others to maximally benefit engagement, suggesting that an alternative explanation might be required.

4.3.Global Contributions

Our results supported the hypothesis (H3) that need-supportive teaching practices have a joint contribution to the prediction of classroom-levels of engagement. More precisely, the global factor (G-factor) reflecting the joint contribution of all three practices to an underlying need-supportive environment, was found to contribute positively to all dimensions of engagement at the classroom level. As such, the presence of averagely high and matching levels of autonomy support, structure, and involvement seems to be a key feature of the classroom environment, as perceived by students, to support all aspects of their math engagement at the classroom level. The specific factors (S-factors), representing the extent to which teachers relied on autonomy support, structure, and involvement independently of this global level, further contributed, in a positive manner, to the prediction of some dimensions of student engagement at the classroom level. For instance, classrooms in which students reported a high level of specific autonomy support perceived that their math teachers offered plenty of choices, listened to students' ideas, and explained why the material was useful, over and above teachers' global use of need-supportive teaching practices. Whereas the contribution of using high levels of autonomy support and involvement beyond the global use of all three practices were respectively specific to emotional engagement and behavioral engagement at the classroom level, high (imbalanced) levels of structure positively contributed to all dimensions of engagement at the classroom level. However, the results pertaining to specific levels of autonomy support and structure should be interpreted with caution and replicated as the classroom level of inter-rater agreement between students for these two practices was lower than for other practices.

Still, finding that high and imbalanced levels of structure benefitted all aspects of engagement at the classroom level may be specific to the math material. Learning math at the secondary school level requires students to manipulate abstract concepts while following specific math rules (Hazzan & Zazkis, 2005). In this context, it is possible that teachers who provide clear expectations, take time to provide constructive feedback, and monitor their students' understanding offer the best possible learning environment for math. As learning other STEM-related subjects also require similar cognitive abstraction levels and share common aspects with math (e.g., computer programming), these results may apply similarly. It would be interesting to assess if the same specific need-supportive practices support different subjects (e.g., Language, arts, physical education), as SDT hypothesizes that similar processes operate regardless of the subject. Overall, together, all three practices jointly sustained student engagement in math at the classroom level (H3), and, contrary to expectations, no risk emerged from the imbalanced use of any of those practices beyond the global level of implementation of the others.

Importantly, in light of the correlation reported between these three teaching practices, this combination of global and imbalanced configuration may also better reflect what really happens in classrooms. It is perhaps not so surprising to find that the bifactor configuration provides an accurate representation of an optimal classroom environment aiming to support student engagement at the classroom level (Garn et al., 2019; Gillet et al., 2019; Sheldon & Niemiec, 2006). Reeve, Deci et al. (2004; also see Reeve, 2012) have argued that need-supportive teachers are those who assess their students' engagement and adjust their practices to meet their students' needs. Hence, these teachers may use more or less of some of these practices at different moments in the day, week, or school year, depending on their students' needs. Although our results are in line with this hypothesis, this feedback loop will have to be formally investigated in future research, which would also benefit from the consideration of teachers' and observers' ratings of teaching practices and engagement.

Two potential areas of discussion stem from these results. First, finding that using imbalanced levels of specific practices had a positive contribution to student engagement was surprising and somewhat unexpected, considering SDT's hypotheses regarding need satisfaction. SDT anticipates that the well-being and positive adjustment of individuals depend on all three needs being satisfied, suggesting that adequately meeting only one need would not be enough (Ryan & Deci, 2017). As such, an imbalance in need satisfaction should bear negative consequences in terms of psychosocial adjustment and well-being (Ryan & Deci, 2017). Yet, our results might suggest that the same process does not apply to the learning environment, more specifically, to math classrooms. Beyond the global contribution of the three practices, additional imbalanced use of specific autonomy support, structure, and involvement positively contributed to some aspects of student engagement. As several students are not intrinsically motivated to learn math, they might benefit from all possible resources from their learning environment to feel engaged (Tytler et al., 2008). This would explain why the global level of need-supportive practices induced higher levels of engagement at the classroom level and why imbalanced perceptions of autonomy support, structure, and involvement had a positive contribution to student engagement at the classroom level.

This brings to a second area of discussion: the mediating role of need satisfaction. Our results assessing the contribution of need-supportive teaching practices are unequivocal regarding their links with student engagement at the classroom level. Although it is now largely accepted that need-supportive teaching practices can directly contribute to student engagement, SDT's original theoretical proposition was that a need-supportive environment would contribute to student engagement through the satisfaction of students' needs for autonomy, competence, and relatedness (Connell & Wellborn, 1991; Deci & Ryan, 2000). This study shows that the three need-supportive practices share important common grounds (the G-factor). Others have similarly demonstrated that the satisfaction of needs for autonomy, competence, and relatedness also share important features (Gillet et al., 2018; 2019; Garn et al., 2019; Litalien et al., 2017; Sánchez-Oliva et al., 2017). Assessing these two concepts through bifactor models to disentangle associations between their global and specific aspects could be an avenue to further the assessment of SDT's original proposition. In particular, it is possible that studying these mechanisms would uncover that specific autonomy support, structure, and involvement are directly linked to specific perceived autonomy, perceived competence, and perceived relatedness, thus proving the original anticipation set forth by SDT. As such, if the same results apply to students' underlying motivation and psychological needs remains to be assessed.

4.4.Limitations

First, the items included in the measures of need-supportive teaching were adapted from a questionnaire originally developed by Belmont et al. (1988). Even if the items used are close to the original ones, it was still interesting to confirm that slight variations in wording did not produce different results. Due to the limited sample size and number of classrooms, coupled with the complexity of our models, we were unable to assess the models using Doubly-Latent Multilevel Modeling, which would have allowed assessing a fully latent model accounting for measurement error and inter-rater reliability (Marsh et al., 2009). Instead, we relied on factor scores (teaching practices and engagement) and on a partial latent aggregation approach (engagement). The latent aggregation approach was applied to engagement because this study conceptualizes it both as a student- and classroom-level concept (involving predictors located at both levels of analyses), whereas we only focus on the classroom-level aspect of teaching practices. This provided a way to account for at least part of the measurement error present in students' ratings (DiStefano et al., 2009). We also note the large standard errors of the regression coefficients at the classroom-level. Moreover, although the SRMRs suggest a good fit of the model both at the student and the classroom levels, authors have demonstrated that separate fit indicators for the within and between levels in multilevel models are not optimal when ICC(1) are low (Hsu et al., 2016), which is the case in this study. For all of these reasons, it would be important to replicate the present results using larger samples of participants and classrooms, allowing for the estimation of more robust doubly latent multilevel models (Marsh et al., 2012).

Although not a limitation per se, this study did not rely on teachers' or observers' ratings, which would have provided an additional perspective on the classroom context and student engagement. Moreover, the present study focused on teachers' practices implemented at the classroom level, which involved addressing a classroom-level research question. However, despite the interest of focusing on classroom-level processes, it is worth reinforcing the equally important role of dyadic student-teacher interactions whereby teachers may come to adapt their generic practices to the specific needs of each student. Although the ratings obtained in the present study did not allow us to consider this equally important level of analysis, it would be interesting for future studies to incorporate both levels of analyses at once to better understand the classroom and individual mechanisms underpinning the effects of these practices. Finally, as discussed, this study was conducted in math classrooms. Learning math requires a level of cognitive abstraction that is also required in other STEM-related subjects. Yet, other subjects require quite different cognitive processes. As such, our results specific to math may not apply similarly to other subjects. It is possible that student engagement in, for instance, language or art courses, is supported by different teacher practices, which prevents the generalizability of our results.

4.5.Future Directions

Results from this investigation are unique in that no existing study has yet assessed the global and imbalanced configuration of need-supportive teaching, especially using bifactor models. Our study supports that bifactor models are well suited to investigate highly interconnected concepts (e.g., Morin, Arens, & Marsh, 2016), as it is the case for teaching practices. Results from this study also confirm the global contribution of need-supportive teaching in math classrooms, which nevertheless ought to be replicated within other school subjects, among students from other age groups, and using samples from different countries. An interesting perspective comes from the fact that, although our study failed to support the synergistic contribution of need-supportive teaching practices, experimental manipulations have supported this hypothesis (Sheldon & Filak, 2008; van Loon, Ros, & Martens, 2012). Our study also showed that not only was support for a global contribution stronger than that for a synergistic contribution. It also showed that this global perspective was likely to provide a more accurate depiction of what happens in the classroom. Furthermore, the experimental support for a synergistic contribution found in these studies was not contrasted to an alternative hypothesis of global contribution. As noted by Gillet et al. (2019), failure to properly contrast these two possibilities may result in erroneous support for a synergistic contribution. It would thus be interesting for experimental studies to devise a way to disentangle these two alternatives hypotheses.

Moreover, our study did not include students' psychological need satisfaction. The needs for competence, autonomy, and relatedness have more than once been shown to be mechanisms linking teaching practices to student engagement (e.g., Wang & Eccles, 2013), and to also match a global hypothesis (e.g., Gillet et al., 2019). Students' needs may also differ from one school subject to another. For example, it seems that the need for competence is highly subject-specific (Bong, 1997). As such, this requires investigating how the learning environments specific to each subject contribute to student engagement through need satisfaction processes. Finally, a few studies show that students with special needs may benefit more than others from some specific classroom features as they also differ in their psychological needs (Jungert & Andersson, 2011; Olivier & Archambault, 2017). These students represent a significant proportion of a classroom and are at increased risk of low engagement. Identifying pedagogical practices that are particularly efficient with these students may provide teachers with strategies to maintain a highly engaged classroom.

4.6.Recommendations for Practice

Studies assessing the additive or synergistic contribution of need-supportive practices often recommend that teachers increase their implementation of one, or more, specific practice, but rarely agree on which practice(s) to prioritize. In contrast to these studies, our results suggest that autonomy support, structure, and involvement in math classrooms globally contribute to a learning environment conducive for student engagement and that a specific focus on increasing one practice over and above the other will not be especially relevant, nor detrimental, for student engagement. It shows that students feel more engaged in classrooms where teachers use high global levels of autonomy support, structure, and involvement. This new finding may bring us closer to finding the environment that best supports student engagement. Unfortunately, it is not yet clear *how* teachers can develop such a global level of practice. Based on our results, it is not possible to draw narrow recommendations that teachers can implement quickly. Instead, it seems that all aspects of need-supportive teaching, as perceived by students, are key ingredients of a classroom supporting engagement.

References

Aelterman, N., Vansteenkiste, M., Haerens, L., Soenens, B., Fontaine, J.R.J., & Reeve, J. (2019). Toward an intergrative and fine-grained insight in motivating and demotivating teaching styles: The merits of a circumplex approach. *Journal of Educational Psychology*, *111*, http://dx.doi.org/10.1037/edu0000293

Archambault, I., & Dupéré, V. (2016). Joint trajectories of behavioral, affective, and cognitive engagement in elementary school. *The Journal of Educational Research, 110*, 188-198. http://doi.org/10.1080/00220671.2015.1060931

Belmont, M.J., Skinner, E.A., Wellborn, J.G., & Connell, J.P. (1988). *Teacher as a social context: A measure of student perceptions of teacher provision of involvement, structure, and autonomy-support*. University of Rochester.

Bean, C., Rocchi, M., & Forneris, T. (2019). Using the Learning Climate Questionnaire to assess basic psychological needs support in youth sport. *Journal of Applied Sport Psychology*, 1-22. doi:10.1080/10413200.2019.1571537

Bong, M. (1997). Generality of academic self-efficacy judgements: Evidence of hierarchical relations. *Journal of Educational Psychology*, *89*, 696-709. http://doi.org/10.1037/0022-0663.89.4.696
Connell, J.P., & Wellborn, J.G. (1991). Competence, autonomy, and relatedness: A motivational analysis of self-system process. In M.R. Gunnar & L.A. Sroufe (Eds.), *Self Process and Development* (pp. 44-77). Erlbaum.
De Naeghel, J., Valcke, M., De Meyer, I., Warlop, N., van Braak, J., & Van Keer, H. (2014). The role of teacher behavior in adolescents’ intrinsic reading motivation. *Reading & Writing, 27*, 1547-1565. http://doi.org/10.1007/s11145-014-9506-3
De Fraine, B., Van Damme, J., Van Landeghem, G., Opdenakker, M.-C., & Onghena, P. (2003). The effect of schools and classes on language achievement. *British Educational Research Journal*, *29*(6), 841-859. http://doi.org/10.1080/0141192032000137330
Deci, E.L., & Ryan, R.M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227-268. http://doi.org/10.1207/s15327965pli1104_01
DiStefano, C., Zhu, M., & Mindrila, D. (2009). Understanding and using factor scores: Considerations for the applied researcher. *Practical Assessment, Research & Evaluation, 14*, 1-11. http://doi.org/10.7275/da8t-4g52
Dysvik, A., Kuvaas, B., & Gagné, M. (2013). An investigation of the unique, synergistic and balanced relationships between basic psychological needs and intrinsic motivation. *Journal of Applied Social Psychology, 43*, 1050-1064. http://doi.org/10.1111/jasp.12068
Fauth, B., Wagner, W., Bertram, C., Göllner, R., Roloff, J., Lüdtke, O., Polikoff, M. S., Klusmann, U., & Trautwein, U. (2019). Don’t blame the teacher? The need to account for classroom characteristics in evaluations of teaching quality. *Journal of Educational Psychology*. Advance online publication. https://doi.org/10.1037/edu0000416
Fédération Wallonie-Bruxelles. (2018). *Les indicateurs de l’enseignement 2018*. Fédération Wallonie-Bruxelles. http://www.enseignement.be
Fédération Wallonie-Bruxelles. (2019). *Évaluations externes certificatives*. Fédération Walloie-Bruxelles. http://www.enseignement.be
Feldon, D.F. (2007). Cognitive load and classroom teaching: The double-edged sword of automaticity. *Educational Psychologist, 42*, 123-137. http://doi.org/10.1080/00461520701416173
Finn, J.D. (1993). *School Engagement & Students at Risk*. National Center for Education Statistics
Fredricks, J.A., Blumenfeld, P.C., & Paris, A.H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*, 59-109. http://doi.org/10.3102/00346543074001059
Galand, B., & Philippot, P. (2005). L'école telle qu'ils la voient: Validation d'une mesure des perceptions du contexte scolaire par les élèves du secondaire. [*School as they see it: Validation of a measure of secondary students' perceptions of the school context*]. *Canadian Journal of Behavioural Science, 37*, 138-154. http://doi.org/10.1037/h0087251
Galand, B., Raucent, B., & Frenay, M. (2010). Engeneering students’ self-regulation, study strategies, and motivational believes in traditional and problem-based curricula. *International Journal of Engineering Education, 26*, 523-534. https://www.ijee.ie/latestissues/Vol26-3/04_Ijee2308.pdf
Garn, A.C., Morin, A.J.S., & Lonsdale, C. (2019). Basic psychological need satisfaction toward learning: A longitudinal test of mediation using bifactor exploratory structural equation modeling. *Journal of Educational Psychology, 111*, 354-372. http://doi.org/10.1037/edu0000283
Gillet, N., Morin, A.J.S., Huart, I., Colombat, P., & Fouquereau, E. (2019). The forest and the trees: Investigating the globality and specificity of employees' basic need satisfaction at work. *Journal of Personality Assessment*, 1-12. http://doi.org/10.1080/00223891.2019.1591426
Gillet, N., Morin, A.J.S., Huart, I., Odry, D., Chevalier, S., Coillot, H., & Fouquereau, E. (2018). Self-determination trajectories during police officers’ vocational training program: A growth mixture analysis. *Journal of Vocational Behavior, 109*, 27-43. http://doi.org/10.1016/j.jvb.2018.09.005
Hazzan, O. & Zazkis, R. (2005). Reducing abstraction: The case of school mathematics. *Educational Studies in Mathematics*, *58*, 101-119. http://doi.org/10.1007/s.10649-005-3335-x
Hedges, L.V., & Hedberg, E.C. (2007). Intraclass correlation values for planning group-randomized trials in education. *Educational Evaluation & Policy Analysis*, 29, 60–87.
Holzberger, D., Praetorius, A., Seidel, T., & Kunter, M. (2019). Identifying effective teachers: The relation

between teaching profiles and students' development in achievement and enjoyment. *European Journal of Psychology of Education*, *34*, 801-823. http://doi.org/10.1007/s10212-018-00410-8

Hospel, V., & Galand, B. (2016a). Are both classroom autonomy support and structure equally important for students' engagement? A multilevel analysis. *Learning & Instruction*, *41*, 1-10. http://doi.org/10.1016/j.learninstruc.2015.09.001

Hospel, V., Galand, B., & Janosz, M. (2016b). Multidimensionality of behavioural engagement: Empirical support and implications. *International Journal of Educational Research, 77*, 37-49. http://doi.org/10.1016/j.ijer.2016.02.007

Jang, H., Reeve, J., & Deci, E.L. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology, 102*, 588-600. http://doi.org/10.1037/a00119682

Jungert, T. & Andersson, U. (2011). Self-efficacy beliefs in mathematics, native language literacy and foreign language amongst boys and girls with and without mathematic difficutlies. *Scandinaviann Journal of Educational Research*, *57*, 1-15. https://doi.org/10.1080/00313831.2011.621140

Klem, A.M., & Connell, J.P. (2004). Relationships matter: Linking teacher support to student engagement and achievement. *Journal of School Health*, *74*, 262-273. http://doi.org/10.1111/j.1746-1561.2004.tb08283.x

Kunter, M., & Baumert, J. (2006). Who is the expert? Construct and criteria validity of student and teacher ratings of instruction. *Learning Environments Research*, *9*, 231-251. http://doi.org/10.1007/s10984-006-9015-7

Leenknecht, M.J.M., Wijnia, L., Loyens, S.M, & Rikers, R.M.J. (2017). Need-supportive teaching in higher education: Configurations of autonomy support, structure, and involvement. *Teaching and Teacher Education*, *68*, 134-142. http://doi.org/10.1016/j.tate.2017.08.020

Leflot, G., Onghena, P., & Colpin, H. (2010). Teacher-child interactions: relations with children's self-concept in second grade. *Infant and Child Development*, *19*, 385-405. http://doi.org/10.1002/icd.672

Lietaert, S., Roorda, D., Laevers, F., Verschueren, K., & De Fraine, B. (2015). The gender gap in student engagement: The role of teachers' autonomy support, structure, and involvement. *British Journal of Educational Psychology*, *85*, 498-518. http://doi.org/10.1111/bjep.12095

Litalien, D., Morin, A.J.S., Gagné, M., Vallerand, R.J., Losier, G.F., & Ryan. R.M. (2017). Evidence of a continuum structure of academic self-determination: A two-study test using a bifactor-ESEM representation of academic motivation. *Contemporary Educational Psychology, 51*, 67-82. http://doi.org/10.1016/j.lindif.2010.08.001

Liu, R., & Chiang, Y. (2019). Who is more motivated to learn? The roles of family background and teacher-student interaction in motivating student learning. *Journal of Chinese Sociology*, *6*, 1-17. http://doi.org/10.1186/s40711-019-0095-z

Lüdtke, O., Marsh, H. W., Robitzsch, A., & Trautwein, U. (2011). A 2x2 taxonomy of multilevel latent contextual models: Accuracy and bias tradeoffs in full and partial error-correction models. *Psychological Methods*, *16*(4), 444-467.

Ludtke, O., Marsh, H. W., Robitzsch, A., Trautwein, U., Asparouhov, T., & Muthen, B. (2008). The multilevel latent covariate model: A new, more reliable approach to group-level effects in contextual studies. *Psychological Methods*, 13(3), 203-229. doi:10.1037/a0012869

Lüdtke, O., Robitzsch, A., Trautwein, U., & Kunter, M. (2009). Assessing the impact of learning environment: How to use student rating of classroom or school characteristics in multilevel modeling in multilevel modeling. *Contemporary Educational Psychology*, *34*, 120-131. http://doi.org/10.1016/j.cedpsych.2008.12.001

Marsh, H.W., Lüdtke, O., Nagengast, B., Trautwein, U., Morin, A.J.S., Abduljabbar, A. S., & Köller, O. (2012). Classroom climate and contextual effects: Conceptual and methodological issues in the evaluation of group-level effects. *Educational Psychologist, 47*, 106-124. http://doi.org/10.1080/00461520.2012.670488

Marsh, H.W., Lüdtke, O., Robitzsch, A., Trautwein, U., Asparouhov, T., Muthen, B., & Nagengast, B. (2009). Doubly-latent models of school contextual effects: Integrating multilevel and structural equation approaches to control measurement and sampling error. *Multivariate Behavioural Research*, *44*, 764-802. http://doi.org/10.1080/00273170903333665

Marsh, H.W., Scalas, L.F., & Nagengast, B. (2010). Longitudinal tests of competing factor structures for the Rosenberg self-esteem scale: Traits, ephemeral artifacts, and stable response styles. *Psychological Assessment*, *22*, 366-381. http://doi.org/10.1037/a0019225

Martin, J.A., Anderson, J., Bobois, J., Way, J., & Vellar, R. (2012). Switching on and switching off in mathematics: An ecological study of future intent and disengagement among middle school students. *Journal of Educational Psychology, 104*, 1-18. http://doi.org/10.1037/a0025988

Morin, A.J.S., Arens, A.K., & Marsh, H. (2016). A bifactor exploratory structural equation modeling framework for the identification of distinct sources of construct-relevant psychometric multidimensionality. *Structural Equation Modeling, 23*, 116-139. http://doi.org/10.1080/10705511.2014.961800

Mouratidis, A., Michou, A., Aelterman, N., Haerens, L., & Vansteenkiste, M. (2018). Begin-of-school-year perceived autonomy-support and structure as predictors of end-of-school-year study efforts and procrastination. *Educational Psychology, 38*, 435-450. http://doi.org/10.1080/01443410.2017.1402863

Mouratidis, A., Vansteenkiste, M., Michou, A., & Lens, W. (2013). Perceived structure and achievement goals as predictors of students' self-regulated learning and affect and the mediating role of competence need satisfaction. *Learning and Individual Differences, 23*, 179-186. http://doi.org/10.1016/j.lindif.2012.09.001

Muthén, L.K., & Muthén, B.O. (2019). *Mplus User's Guide*. Los Angeles: Muthén & Muthén.

Nie, Y., & Lau, S. (2009). Complementary roles of care and behavioral control in classroom management. *Contemporary Educational Psychology, 34*, 185-194. http://doi.org/10.1016/j.cedpsych.2009.03.00

OECD. (2017). *Education at a Glance 2017: OECD indicators*. Paris, Fance: OECD.

Olivier, E., & Archambault, I. (2017). Hyperactivity, inattention, and student engagement: The protective role of relationships with teachers and peers. *Learning & Individual Differences, 59*, 86-95. http://doi.org/10.1016/j.lindif.2017.09.007

Olivier, E., Galand, B., Hospel, V., & Dellisse, S. (2020). Understanding behavioural engagement and achievement: The roles of teaching practices and student sense of competence and task value. *British Journal of Educational Psychology*. Early View. http://doi.org/10.1111/bjep.12342

Opdenakker, M.-C., & Van Damme, J. (2001). Relationship between school composition and characteristics of school process and their effect on mathematics achievement. *British Educational Research Journal, 27*, 407-432. http://doi.org/10.1080/0141192012007143

Pokormy, S.B., Jason, L.A., Schoeny, M.E., Townsend, S.M., & Curie, C.J. (2001). Do participation rates change when active consent procedures replace passive consent. *Evaluation Review, 25*, 567-580. http://doi.org/10.1177/0193841x0102500504

Raudenbush, S.W., & Bryk, A.S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Sage.

Reeve, J. (2012). A Self-Determination Theory perspective on student engagement. In S.L. Christenson, A.L. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 149-172). Springer.

Reeve, J., Deci, E., & Ryan, R.M. (2004). Self-determination theory: A dialectical framework for understanding socioocultural influences on student motivation. In D. McInerney & S. Van Etten (Eds.), *Research on sociocultural influences on motivation and learning: Big theories revisited* (pp. 31-59). Information Age.

Reeve, J., & Halusic, M. (2009). How K-12 teachers can put self-determination theory principles into practice. *Theory & Research in Education, 7*, 145-154. http://doi.org/10.1177/1477878509104319

Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). Enhancing students' engagement by increasing teachers' autonomy support. *Motivation and Emotion, 28*, 147-169. http://doi.org/10.1023/B:MOEM.0000032312.95499.6f

Rutkowski, D., & Rutkowski, L. (2013). Measuring socioeconomic background in PISA: One size might not fit all. *Research in Comparative and International Education, 8*, 259-278. http://doi.org/10.2304/rcie.2013.8.3.259

Ruzek, E. A., Hafen, C. A., Allen, J. P., Gregory, A., Mikami, A. Y., & Pianta, R. C. (2016). How teacher emotional support motivates students: The mediating roles of perceived peer relatedness, autonomy support, and competence. *Learning and Instruction, 42*, 95-103. http://doi.org/10.1016/j.learninstruc.2016.01.004

Ryan, R.M., & Deci, E.L. (2000). Self-Determination Theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*, 68-78. http://doi.org/10.1207/s15327965pli1104_01

Ryan, R.M., & Deci, E.L. (2017). *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*. The Guildford Press.

Sánchez-Oliva, D., Morin, A.J.S., Teixeira, P.J., Carraça, E.V., Palmeira, A.L., & Silva, M.N. (2017). A bifactor exploratory structural equation modeling representation of the structure of the basic psychological needs at work scale. *Journal of Vocational Behavior, 98*, 173-187. http://doi.org/10.1016/j.jvb.2016.12.001

Sheldon, K.M., & Filak, V. (2008). Manipulating autonomy, competence, and relatedness support in a game-learning context: New evidence that all three needs matter. *British Journal of Social Psychology, 47*, 267-283. http://doi.org/10.1348/014466607X238797

Sheldon, K.M., & Niemiec, C.P. (2006). It's not just the amount that counts: Balanced need satisfaction also affects well-being. *Journal of Personality & Social Psycholology, 91*, 331-341. http://doi.org/10.1037/0022-3514.91.2.331

Sierens, E., Vansteenkiste, M., Goossens, L., Soenens, B., & Dochy, F. (2009). The synergistic relationship of perceived autonomy support and structure in the prediction of self-regulated learning. *British Journal of Educational Psychology, 79*, 57-68. http://doi.org/10.1348/000709908X304398

Skinner, E.A., & Belmont, M. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology, 85*, 571-581. http://doi.org/10.1037/0022-0663.85.4.571

Skinner, E.A., Furrer, C., Marchand, G., & Kindermann, T. (2008). Engagement and disaffection in the classroom. *Journal of Educational Psychology, 100*, 765-781. http://doi.org/10.1037/a0012840

Stroet, K., Opdenakker, M.-C., & Minnaert, A. (2013). Effects of need supportive teaching on early adolescents' motivation and engagement: A review of the literature. *Educational Research Review, 9*, 65-87. http://doi.org/10.1016/j.edurev.2012.11.003

Tóth-Király,I., Morin, A.J.S., Bőthe, B., Orosz, G., & Rigó, A. (2018). Investigating the multidimensionality of need fulfillment: A bifactor exploratory structural equation modeling representation. *Structural Equation Modeling*, 25, 267-286. doi: 10.1080/10705511.2017.1374867

Tóth-Király, I., Morin, A.J.S., Gillet, N., Bőthe, B., Nadon, L., Rigó, A., & Orosz, G. (In Press). Refining the assessment of need supportive and need thwarting interpersonal behaviors using the bifactor exploratory structural equation modeling framework. *Current Psychology*. http://doi.org/10.1007/s12144-020-00828-8

Tucker, C.M., Zayco, R.A., Herman, K.C., Reinke, W.M., Trujillo, M., Carraway, K., Wallack, C., Ivery, P.D. (2002). Teacher and child variables as predictors of academic engagement among low-income African American children. *Psychology in the Schools, 39*, 477-488. http://doi.org/10.1002/pits.10038

Tytler, R., Osborne, J., Williams, G., Tytler, K., & Cripps Clark, J. (2008). *Opening up pathways: Engagement in STEM across the primary-secondary school transition*. Australian Department of Education, Employment and Worplace Relations.

van Loon, A., Ros, A., & Martens, R. (2012). Motivated learning with digital learning tasks: what about autonomy and structure? *Educational Technology Research & Development, 60*, 1015-1032. http://doi.org/10.1007/s11423-012-9267-0

Vansteenkiste, M., Sierens, E., Goossens, L., Soenens, B., Dochy, F., Mouratidis, A., Aelterman, N., Haerens, L., Beyers, W. (2012). Identifying configurations of perceived teacher autonomy support and structure: Associations with self-regulated learning, motivation and problem behavior. *Learning and Instruction, 22*, 431-439. http://doi.org/10.1016/j.learninstruc.2012.04.002

Véronneau, M.-H., Vitaro, F., Brendgen, M., Dishion, T.J., & Tremblay, R.E. (2010). Transactional analysis of the reciprocal links between peer experiences and academic achievement from middle childhood to early adolescence. *Developmental Psychology, 46*, 773-790. http://doi.org/10.1037/a0019816

Wagner, W., Göllner, R., Werth, S., Voss, T., Schmitz, B., & Trautwein, U. (2016). Student and teacher ratings of instructional quality: Consistency of ratings over time, agreement, and predictive power. *Journal of Educational Psychology*, *108*(5), 705–721. https://doi.org/10.1037/edu0000075

Wang, M.T. & Degol, J. (2014). Motivational pathways to STEM career choices: Using expectancy-value perspective to understand individual and gender differences in STEM fields. *Developmental Review*, *3*(4) 304-340. http://doi.org/10.1016/j.dr.2013.08.001

Wang, M.T., & Eccles, J.S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence, 22*, 31-39. http://doi.org/10.1111/j.1532-7795.2011.00753.x

Wang, M.T., & Eccles, J.S. (2013). School context, achievement motivation, and academic engagement: A longitudinal study of school engagement using a multidimensional perspective. *Learning & Instruction, 28*, 12-23. http://doi.org/10.1016/j.learninstruc.2013.04.002

Wang, M.T., & Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal*, *47,* 633-662. http://doi.org/10.3102/0002831209361209

Weyns, T., Colpin, H., De Laet, S., Engels, M., & Verschueren, K. (2018). Teacher support, peer acceptance, and engagement in the classroom: A three-wave longitudinal study in late childhood. *Journal of Youth & Adolescence, 47,* 1139-1150. http://doi.org/10.1007/s10964-017-0774-5

Xue, Y., & Larson, R.C. (2015). STEM crisis or STEM surplus? Yes and yes. *Monthly Labor Review, U.S. Bureau of Labor Statistics*. http://doi.org/10.21916/mlr.2015.14

Zhang, T., Solomon, M. A., & Gu, X. (2012). The role of teachers' support in predicting students' motivation and achievement outcomes in physical education. *Journal of Teaching in Physical Education*, *31*, 329-343. https://journals.humankinetics.com

Zhao, W., Song, Y., Zhao, Q., & Zhang, R. (2018). The effect of teacher support on primary school students' reading engagement: the mediating role of reading interest and chinese academic self-concept. *Educational Psychology*, *39,* 1-18. http://doi.org/10.1080/01443410.2018.1497146

Zimmer-Gembeck, M.J., Chipuer, H., Hanisch, M., Creed, P., & McGregor, L. (2006). Relationships at school and stage-environment fit as resources for adolescent engagement and achievement. *Journal of Adolescence*, *29*, 911-933. http://doi.org/10.1016/j.adolescence.2006.04.008

Table 1

Literature review.

Study	Sample	Variables included	Methods	Analyses	Results	Support for hypothesis?
			Additive contribution[1]			
De Naeghel et al. (2014)	15 y.o. students	A, S, I EE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: YES (school level)	Regression	A → EE S → EE I → EE	YES (at the school level)
Leflot et al. (2010)	2nd graders	A, S, I BE	Practices rated by: TEACHER Control for prior eng.: YES Multilevel analyses: NO	Regression	A → no association; S → no association; I → no association	NO
Lietaert et al. (2015)	7th graders	A, S, I BE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: NO	Structural equation modeling	A → BE S → no association I → BE	NO
Skinner and Belmont (1993)	3rd to 5th graders	A, S, I BE, EE	Practices rated by: STUDENT Control for prior eng.: YES Multilevel analyses: NO	Regression	A → no association; S → BE I → EE	NO
Wang and Eccles (2013)	7th graders followed in 8th grade	A, S, I BE, EE, CE	Practices rated by: STUDENT Control for prior eng.: YES Multilevel analyses: YES (school level)	Regression	A → BE, EE, CE S → BE, EE I → BE, EE	YES (at the school level)
			Synergistic contribution[2]			
Holzberger et al. (2019)	9th graders followed in 10th grade	A, S, I EE	Practices rated by: STUDENT Control for prior eng.: YES Multilevel analyses: YES (classroom level)	Latent Profile Analysis	3 profiles combining 11 practices, including A, S, I: Low all; Moderate all; High all (no synergistic configuration) No association between the profiles and EE	NO
Hospel & Galand (2016)	9th graders	A, S BE, EE, CE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: YES (classroom level)	Regression Two-way interactions	A × S → EE Interaction not associated with BE or CE	PARTIAL
Leenknecht et al. (2017)	Higher education	A, S, I	Practices rated by: STUDENT Control for prior eng.: N/A Multilevel analyses: NO	Cluster analysis	3 clusters combining A, S, and I: Low all; Moderate all; High all (no synergistic configuration)	NO
Mouratidis et al. (2018)	7th to 12th graders	A, S BE	Practices rated by: STUDENT Control for prior eng.: YES Multilevel analyses: YES (classroom level)	Regression Two-way interaction	A × S → no association	NO
Nie and Lau	9th graders	A, S	Practices rated by: STUDENT	Regression	A × S → no association	NO

Study	Sample	Variables included	Methods	Analyses	Results	Support for hypothesis?
(2009)		BE	Control for prior eng.: NO Multilevel analyses: YES (classroom level)	Two-way interaction		
Sierens et al. (2009)	11th and 12th graders	A, S CE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: NO	Regression Two-way interaction	A × S → CE	YES
Vansteenkiste et al. (2012)	7th to 12th graders	A, S CE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: NO	Cluster analysis MANOVA	4 clusters combining A and S: Low all; Low A–High S; High A–Low S; High all CE is higher in the High all configuration	YES
Global contribution[3]						
Klem and Connell (2004)	3rd to 8th graders	A, S, I BE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: NO	Mean score of A, S, and I items (and then cutoffs) Frequencies	Global measure A, S, I → BE	YES
Skinner et al. (2008)	4th to 7th graders	A, S, I BE, EE	Practices rated by: STUDENT Control for prior eng.: YES Multilevel analyses: NO	Mean score of A, S, and I items	Global measure A, S, I → BE, EE	YES
Tucker et al. (2002)	1st to 12th graders	A, S, I BE, EE, CE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: NO	Composite score of A, S, and I Regression	Global measure A, S, I → Global measure BE, EE, CE	YES
Zimmer-Gembeck et al. (2006)	10th and 11th graders	A, S, I BE, EE	Practices rated by: STUDENT Control for prior eng.: NO Multilevel analyses: NO	Structural equation modeling	Global measure A, S, I → Global measure BE, EE	YES

Note. A=autonomy support; S=structure; I=involvement; BE=behavioral engagement; EE=emotional engagement; CE=cognitive engagement.
The literature review was conducted using PsycINFO and Google Scholar. The keywords used to represent teaching practices were: *self-determination*, *need-supportive*, *autonomy support*, *structure*, *involvement*, and *teacher*. The keywords used to represent student engagement were *student engagement/motivation*, *classroom engagement/motivation*, *school engagement/motivation*, *academic engagement/motivation*. The search was restricted to peer-reviewed articles. We also when through the reference list of the retained articles. Only studies in which direct associations between teaching practices and student engagement were assessed are included in the table. Studies assessing mediators without the direct associations were not included.
[1] Only studies that included all three dimensions of teacher practices are included in the Additive contribution list.
[2] Studies included in the Synergistic contribution list are those that have assessed the clusters or interactions between two or three practices grounded in SDT.
[3] Studies included in the Global contribution list are those that have assessed a general measure of teacher practices that included all three practices in a single measure. None of these studies specifically refer to a global configuration, and none has assessed bifactor models.

Table 2

Correlations

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
1.Behav.Eng. (Gr. 7)		.59**	.96**	.05	.28*	.08	-.28*	.38**	.16	.18	.17	.17	-.16	-.05	.17	.32*	.31*	.36*
2.Emo. Eng. (Gr. 7)	.58**		.78**	.00	.08	-.03	-.03	.22	.28*	.25	.25	.26	.21	-.06	.06	.17	.37**	.24
3.Cog. Eng. (Gr. 7)	.86**	.61**		.11	.33*	.13	-.32*	.43**	.12	.14	.13	.13	-.15	-.06	.18	.32*	.31*	.35**
4.Gender	.04	-.04	.05		-.03	-.03	-.10	.05	-.06	-.05	-.05	-.05	-.13	.15	-.08	-.04	.03	.02
5.Educative Possessions	.13**	.11**	.15**	.06		.44**	-.58**	.56**	-.09	-.04	-.01	-.05	-.40**	-.05	.31*	.17	-.07	.17
6.Educative Resources	.09*	.14**	.08*	-.04	.12**		-.29*	.39**	.06	.08	.13	.08	-.11	.03	.31*	.12	.06	.11
7.Grade Retention	-.12**	-.04	-.10**	-.03	-.19**	-.04		-.69**	.05	.00	-.04	.00	.45**	.11	-.29*	-.14	.12	-.15
8.Math. Knowled. (Gr. 7)	.17**	.14**	.17**	-.13**	.17**	.11**	-.37**		.20	.22	.27*	.22	-.23	-.05	.42**	.25	.06	.28*
9.Autonomy Supp.(CFA)	.24**	.24**	.24**	.01	-.04	.04	-.02	.05		.95**	.90**	.99**	.25	.21	.30*	.52**	.70**	.55**
10.Structure (CFA)	.25**	.23**	.25**	.00	-.03	.05	-.04	.06	.91**		.91**	.99**	.13	.25	.32*	.55**	.68**	.58**
11.Involvement (CFA)	.24**	.22**	.24**	.02	-.01	.06	-.04	.06	.84**	.90**		.99**	.09	.11	.48**	.53**	.67**	.56**
12.Autonomy Sup.(bifactor)	.25**	.23**	.25**	.01	-.03	.05	-.03	.05	.98**	.99**	.97**		.15[1]	.20[1]	.33*[1]	.53**	.68**	.56**
13.Structure (bifactor)	-.01	.06	.00	.02	-.07*	-.05	.07*	-.04	.31**	.13**	.08**	.14**[1]		-.09[1]	-.24[1]	-.09	.26	-.04
14.Involvement (bifactor)	.04	.00	.02	-.07*	-.03	.03	-.04	.06	.10**	.20**	.06*	.12**[1]	-.15**[1]		-.30*[1]	.33*	.20	.27*
15.Global practices (bifactor)	.06	.03	.05	.04	.12**	.08**	-.07*	.05	.06*	.10**	.30**	.11**[1]	-.22**[1]	-.18**[1]		.32*	.32*	.35**
16.Behav.Eng. (Gr. 8)	.61**	.43**	.60**	-.00	.17**	.11**	-.14**	.17**	.44**	.45**	.43**	.45**	.05	.06	.09**		.59**	.96**
17.Emo. Eng. (Gr. 8)	.42**	.48**	.45**	-.10**	.11**	.14**	-.09**	.16**	.48**	.47**	.45**	.47**	.13**	.05	.05	.66**		.95**
18.Cog. Eng. (Gr. 8)	.58**	.46**	.62**	.02	.20**	.12**	-.14**	.17**	.44**	.45**	.43**	.45**	.06*	.05	.08**	.86**	.65**	

Note. * p<.05. ** p<.01.

Student-level correlations are displayed below the diagonal and classroom-level correlations are displayed above the diagonal.

[1] Despite the orthogonality of bifactor model (where all latent factors are uncorrelated), the correlations reported in this Table involve factor scores saved at the student level which only provide an imperfect reflection of these latent correlations and thus display close to 0 (rather than exactly 0) correlations. Thus, these correlations cannot be interpreted.

Table 3

Multilevel Models 0.1 to 0.3.

	Model 0.1: Autonomy support						Model 0.2: Structure						Model 0.3: Involvement					
	Beh. Eng.		Emo. Eng.		Cog. Eng.		Beh. Eng.		Emo. Eng.		Cog. Eng.		Beh. Eng.		Emo. Eng.		Cog. Eng.	
	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*
Student Level																		
Beh.Eng. Gr.7	.34(.03)	<.001					.34(.03)	<.001					.34(.03)	<.001				
Emo. Eng. Gr.7			.28(.04)	<.001					.28(.04)	<.001					.28(.04)	<.001		
Cog. Eng. Gr.7	.28(.05)	<.001	.25(.04)	<.001	.61(.04)	<.001	.28(.05)	<.001	.24(.04)	<.001	.61(.04)	<.001	.28(.05)	<.001	.24(.04)	<.001	.61(.04)	<.001
Gender			-.07(.02)	<.001					-.07(.02)	<.001					-.07(.02)	<.001		
Educ. Poss.	.06(.02)	.005			.07(.02)	<.001	.05(.02)	.005			.07(.02)	<.001	.05(.02)	.005			.07(.02)	<.001
Educ. Resources	.06(.03)	.021	.09(.03)	.005	.08(.02)	.002	.06(.03)	.022	.09(.03)	.006	.08(.02)	.002	.06(.03)	.024	.09(.03)	.006	.08(.02)	.002
Grade Retention																		
Math.Know. Gr.7			.04(.02)	.042					.04(.02)	.041					.04(.02)	.046		
Classroom Level																		
Autonomy	.15(.05)	<.001	.16(.04)	<.001	.16(.05)	<.001												
Structure							.15(.05)	<.001	.16(.04)	<.001	.16(.05)	<.001						
Involvement													.14(.05)	.002	.15(.04)	<.001	.15(.05)	<.001
Classroom-level explained variance	47.92%		85.71%		58.14%		52.08%		80.95%		60.47%		47.92%		80.95%		55.81%	

Table 4

Multilevel Models 1 to 3.

	Model 1: Additive Contribution						Model 2: Synergistic Contribution						Model 3: Global Contribution					
	Beh. Eng.		Emo. Eng.		Cog. Eng.		Beh. Eng.		Emo. Eng.		Cog. Eng.		Beh. Eng.		Emo. Eng.		Cog. Eng.	
	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*	ß(SE)	*p*
Student Level																		
Beh.Eng. Gr.7	.35(.03)	<.001					.35(.03)	<.001					.35(.03)	<.001				
Emo. Eng. Gr.7			.28(.04)	<.001					.28(.04)	<.001					.28(.04)	<.001		
Cog. Eng. Gr.7	.27(.05)	<.001	.27(.04)	<.001	.61(.04)	<.001	.27(.05)	<.001	.25(.04)	<.001	.62(.04)	<.001	.27(.04)	<.001	.24(.04)	<.001	.61(.04)	<.001
Gender			-.07(.02)	<.001					-.07(.02)	<.001					-.07(.02)	<.001		
Educ. Poss.	.05(.02)	.007			.07(.02)	<.001	.05(.02)	.009			.07(.02)	<.001	.05(.02)	.008			.07(.02)	<.001
Educ. Resources	.06(.03)	.028	.08(.03)	.006	.07(.03)	.003	.06(.03)	.017	.09(.03)	.006	.08(.02)	.002	.06(.03)	.030	.08(.03)	.009	.08(.03)	.003
Grade Retention																		
Math.Know. Gr.7			.05(.02)	.004					.05(.03)	.036					.05(.02)	.051		
Classroom Level																		
Autonomy	-.28(.23)	.234	.32(.21)	.124	-.04(.22)	.862	-.34(.22)	.120	.33(.20)	.093	-.12(.20)	.550						
Structure	.55(.29)	.056	-.11(.24)	.650	.28(.27)	.312	.60(.26)	.020	.02(.24)	.943	.34(.25)	.171						
Involvement	-.13(.15)	.392	-.05(.11)	.640	-.08(.15)	.640	-.14(.15)	.355	-.19(.11)	.078	-.08(.16)	.614						
Auto.×Stru.							.09(.27)	.732	.54(.27)	.045	.06(.28)	.832						
Auto.×Invo.							-.72(.39)	.061	-.93(.51)	.067	-.70(.39)	.068						
Stru.×Invo.							.57(.34)	.096	.37(.38)	.332	.58(.34)	.090						
Global Practices													.10(.04)	.014	.11(.04)	.002	.11(.04)	.004
Specific Auto.													.02(.04)	.610	.07(.03)	.007	.03(.03)	.325
Specific Stru.													.11(.04)	.002	.07(.03)	.030	.09(.04)	.019
Specific Invo.													.08(.04)	.039	.06(.03)	.082	.07(.04)	.063
Classroom-level explained variance	56.25%		85.71%		62.79%		68.75%		95.24%		76.74%		62.50%		85.71%		65.12%	

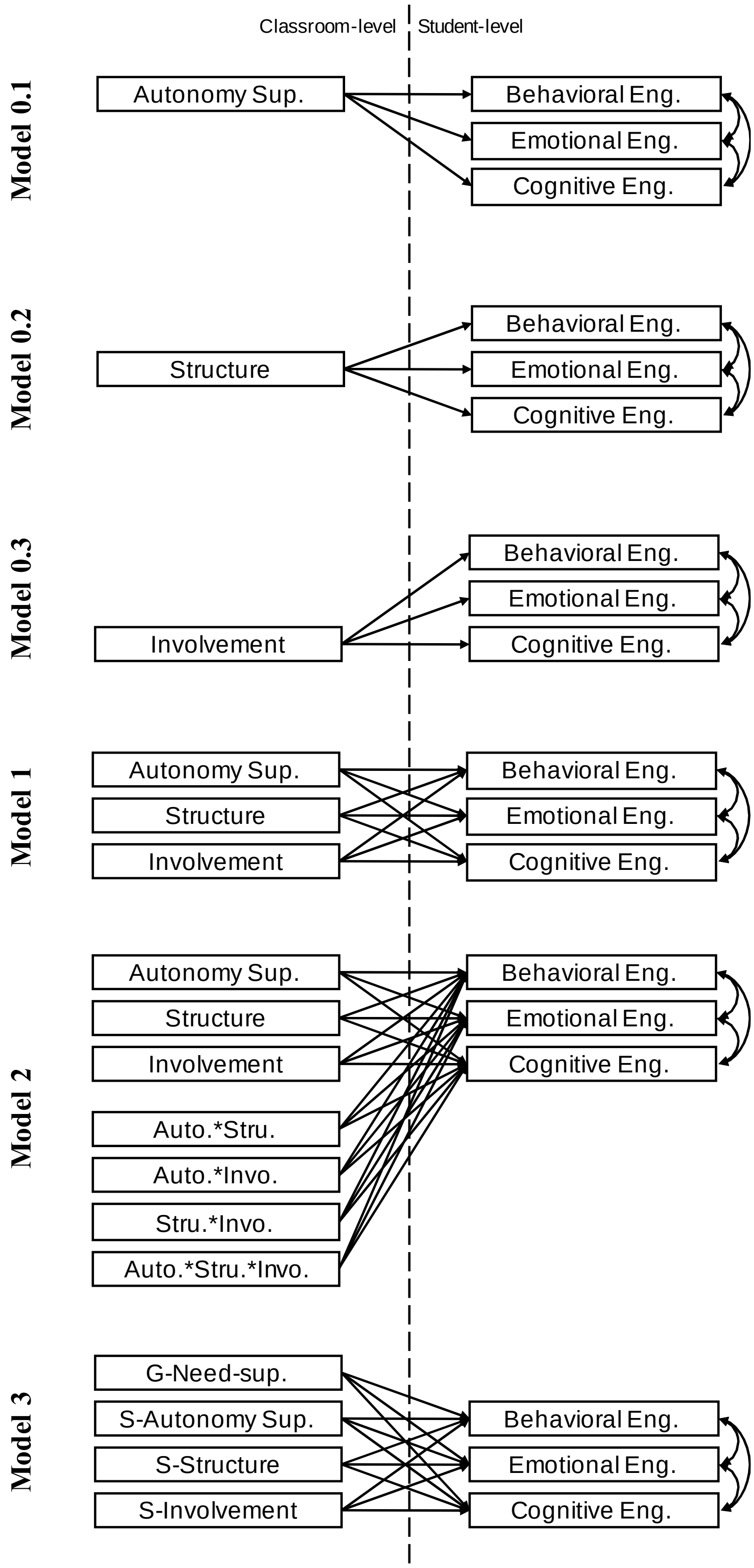

Figure 1. Model description.

Note. Correlations between the predictors are automatically taken into account as part of the model estimation procedures, but not indicated in the figure to void cluttering.

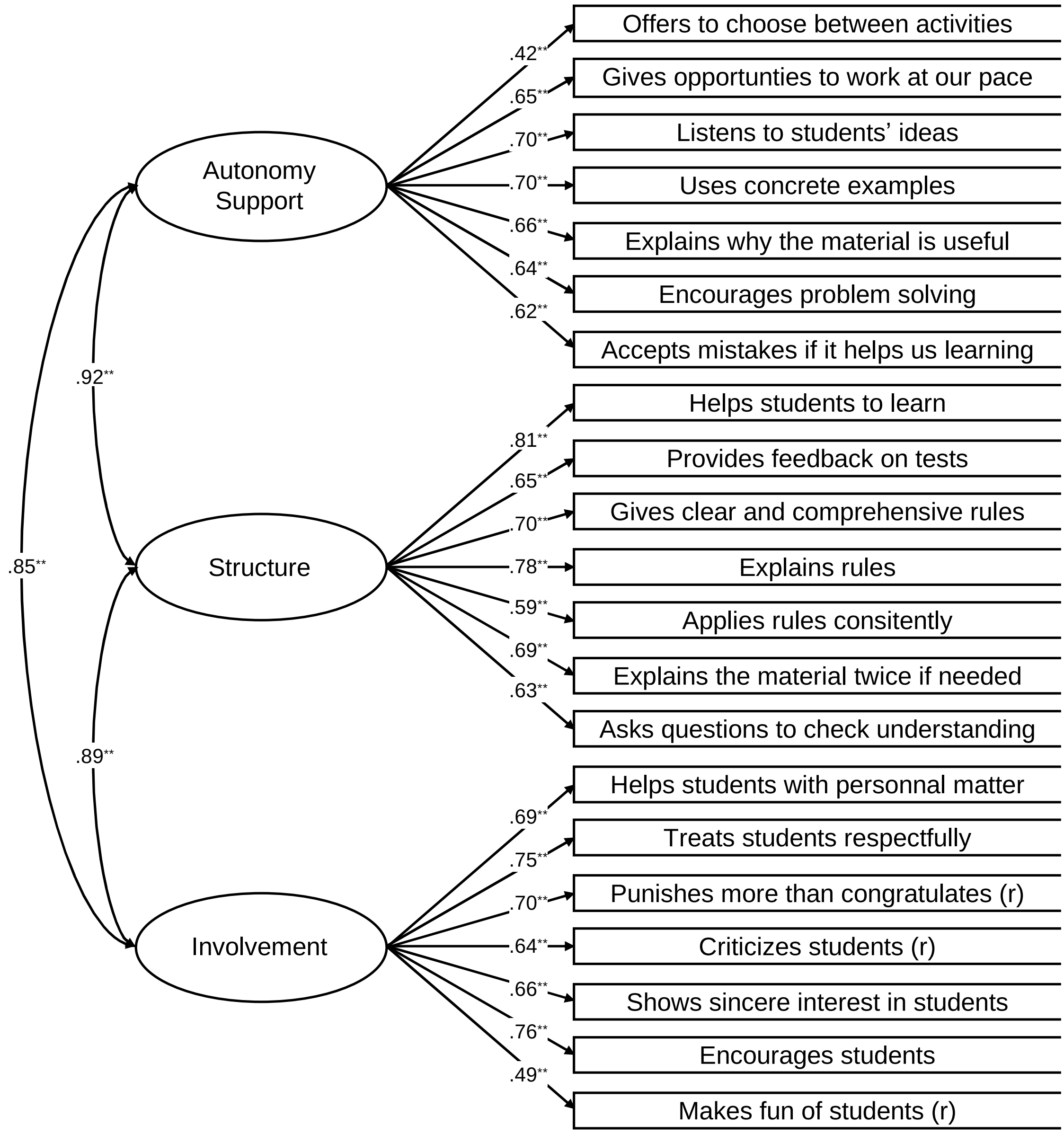

Figure 2. CFA with teacher practices.

Note. * *p*<.05. ** *p*<.01. (r)=reverse coded item.
Goodness of fit: χ^2=934.103, df=103, *p*<.001; CFI=.961; TLI=.955; RMSEA=.036. A priori correlated uniquenesses between the negatively-worded items were included in the CFA model (Marsh, Scalas, & Nagengast, 2010).

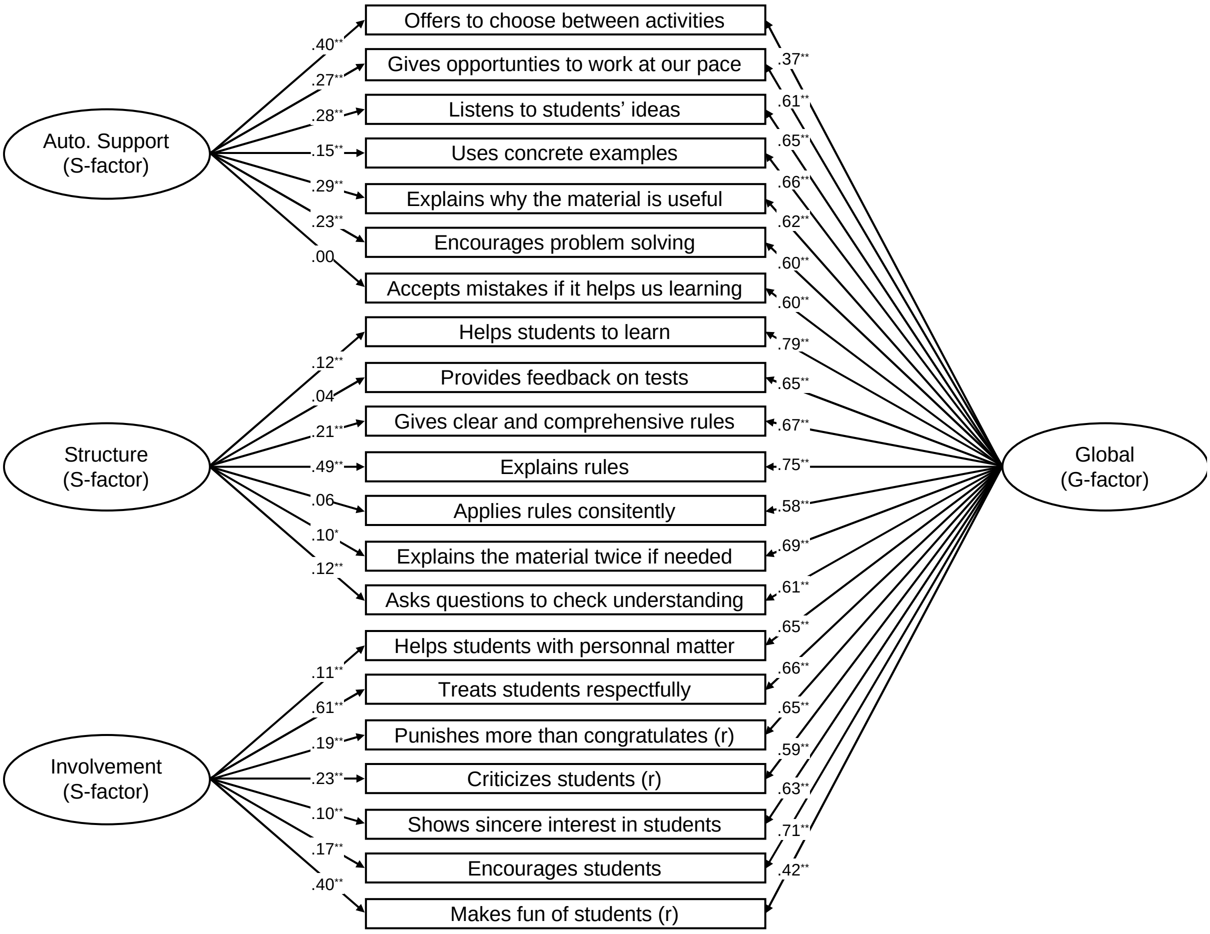

Figure 3. Bifactor CFA with teacher practices.

Note. * *p*<.05. ** *p*<.01. (r)=reverse coded item.
Goodness of fit: χ^2=779.459, df=165, *p*<.001; CFI=.968; TLI=.960; RMSEA=.032. A priori correlated uniquenesses between the negatively-worded items were included in the Bifactor CFA model (Marsh, Scalas, & Nagengast, 2010). Bifactor models are, by definition, orthogonal (with all correlations between factors fixed to be 0; Morin, Arens, & Marsh, 2016).

Appendix A

Table A1. Confirmatory Factor Analytic Results for Student Engagement

	T1 Loading	T2 Loading
Behavioral Engagement		
1. I do what the teacher asks.	.721**	.722**
2. I pretend to work in math classes. (reverse coded)	.523**	.636**
3. I follow the teacher's instructions.	.675**	.662**
4. I daydream or think of other things. (reverse coded)	.563**	.560**
5. I do math exercises carefully.	.713**	.742**
6. I do other thinks in class (text messages, listen to music). (reverse coded)	.484**	.479**
7. When the teacher asks a question during a class, I try to answer.	.603**	.676**
8. I chat with others during lessons.	.434**	.401**
9. I listen to the teachers' lessons.	.825**	.852**
10. I am attentive and focused.	.798**	.763**
Emotional Engagement		
1. I feel happy and fulfilled.	.785**	.777**
2. I am proud of myself.	.643**	.762**
3. I am cheerful and interested.	.712**	.685**
4. I am discouraged and spiritless. (reverse coded)	.539**	.517**
5. I am confident and optimistic.	.659**	.683**
6. I am reluctant and unwilling. (reverse coded)	.424**	.420**
7. I am curious and fascinated.	.492**	.612**
Cognitive Engagement		
1. I do not let myself be distracted during math lessons.	.670**	.675**
2. I underline important information when I study the math material.	.414**	.438**
3. I try to identify the important information when solving math problems.	.624**	.633**
4. I check for mistakes before handing in assignments.	.590**	.617**
5. I put extra effort when facing a difficulty.	.502**	.571**
6. I try to connect new material with what I already know.	.529**	.587**
7. I try to connect new material with what I already know.	.537**	.542**
8. I strive to stay focused even when I am not interested in the material.	.692**	.449**
9. I try to understand what we learn in math.	.585**	.585**
10. I give up when I do not understand the material. (reverse coded)	.526**	.594**
11. I ask for explanations when I don't understand the material.	.398**	.492**

Note. * p<.05. ** p<.01.

Goodness of fit: χ^2=1463.08 (df =352), p<.001; RMSEA=.05 CFI=.91; TLI=.90. Students were asked to rate all items in reference to their math course. A priori correlated uniquenesses between the negatively-worded items were included in the CFA model (Marsh, Scalas, & Nagengast, 2010).

Appendix B

Table B1. Measurement invariance test across sex and time

Model	χ^2	*df*	CFI	TLI	RMSEA	RMSEA 90% CI	$\Delta\chi^2$	Δdf	ΔCFI	ΔTLI	ΔRMSEA
					Student engagement						
CFA invariance between T1 and T2											
1. Configural invariance	4107.492*	1399	.921	.913	.040	.039-.042	–	–	–	–	–
2. Weak invariance	4084.963*	1424	.922	.916	.040	.038-.041	5.005*	25	+.001	+.003	+.000
3. Strong invariance	4412.723*	1505	.915	.913	.040	.039-.042	508.054*	81	-.007	-.003	+.000
4. Strict invariance	4392.296*	1533	.916	.916	.040	.038-.041	17.814*	28	+.001	+.003	+.000
5. Latent variance invariance	4138.494*	1560	.925	.926	.037	.036-.039	44.606*	27	+.009	+.010	-.003
6. Latent mean invariance	4529.590*	1563	.913	.915	.040	.039-.041	161.485*	3	-.012	-.011	+.003
CFA invariance between student sex											
1. Configural invariance	2215.781*	652	.926	.914	.065	.062-.068	–	–	–	–	–
2. Weak invariance	2176.700*	677	.929	.920	.062	.060-.065	74.673*	25	+.003	+.006	-.003
3. Strong invariance	2335.512*	758	.925	.925	.061	.058-.063	276.510*	81	-.004	+.005	-.001
4. Strict invariance	217.645*	789	.934	.937	.056	.053-.059	62.682*	28	+.009	+.012	-.005
5. Latent variance invariance	1717.630*	813	.957	.960	.044	.041-.047	37.522	27	+.023	+.023	-.012
6. Latent mean invariance	1731.690*	816	.956	.960	.044	.042-.047	13.922*	3	-.001	+.000	+.000
					Teaching practices						
CFA invariance between student sex											
1. Configural invariance	1124.744*	366	.96	.955	.060	.056-.064	–	–	–	–	–
2. Weak invariance	1329.583*	384	.951	.946	.066	.062-.070	148.201*	18	-.009	-.009	+.006
3. Strong invariance	1353.019*	444	.953	.955	.060	.056-.064	11.493*	60	+.002	+.009	-.006
4. Strict invariance	1332.719*	465	.955	.959	.057	.054-.061	79.790*	21	+.002	+.004	-.003
5. Latent variance invariance	99.959*	474	.973	.976	.044	.040-.048	16.568	9	+.018	+.017	-.013
6. Latent mean invariance	96.148*	477	.975	.978	.042	.038-.046	2.826	3	+.002	+.002	-.002
Bifactor-CFA invariance between student sex											
1. Configural invariance	981.779*	330	.966	.957	.059	.055-.063					
2. Weak invariance	1062.215*	368	.964	.959	.058	.054-.062	129.849*	38	-.002	+.002	-.001
3. Strong invariance	1125.207*	427	.964	.964	.054	.050-.058	153.645*	59	+.000	+.005	-.004
4. Strict invariance	1137.954*	448	.964	.966	.052	.048-.056	96.689*	21	+.000	+.002	-.002
5. Latent variance invariance	844.312*	455	.980	.981	.039	.035-.043	1.539	7	+.016	+.015	-.013
6. Latent mean invariance	825.535*	459	.981	.982	.038	.033-.042	4.764	4	+.001	+.001	-.001

Note. $^*p<.05$; χ^2: Chi square test of model fit and associated degrees of freedom (*df*); CFI: Comparative Fit Index; TLI: Tucker-Lewis Index; RMSEA: Root Mean Square Error of Approximation and 90% Confidence Interval (CI); Δ: Change according to the previous retained model; $\Delta\chi^2$: Chi square difference test calculated with the Mplus DIFFTEST option for the measurement invariance model.